Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Revision of Part 15 of the Commission's Rules	)	ET Docket No. 13-49
to Permit Unlicensed National Information	)	
Infrastructure (U-NII) Devices in the 5 GHz	)	
Band	)	

COMMENTS OF THE ALLIANCE OF AUTOMOBILE MANUFACTURERS, INC. AND THE ASSOCIATION OF GLOBAL AUTOMAKERS, INC.

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EXECUTIVE SUMMARY

Although the Alliance of Automobile Manufacturers ("Alliance") and the Association of Global Automakers ("Global") understand the Commission's desire to unleash additional spectrum for Unlicensed National Information Infrastructure ("U-NII") use, we have grave concerns about allowing such use of the 5850-5925 MHz ("5.9 GHz") Dedicated Short Range Communications Service ("DSRC") band. DSRC holds great promise for improving the safety of United States roadways and substantially enhancing the efficiency of the U.S. highway transportation system. Significant progress has been made toward its widespread deployment. At the cusp of a deployment decision by the National Highway Traffic Safety Administration ("NHTSA"), this potentially life-saving technology will only be effective and viable if it can operate in an interference-free environment.

As discussed more fully below, the Alliance and Global are skeptical that, as proposed by the Commission, U-NII devices will be able to share, or operate in close spectral proximity to, the 5.9 GHz DSRC band without causing severe and persistent, harmful interference to DSRC vehicle-to-vehicle ("V2V") and vehicle-to-infrastructure ("V2I") communications. U-NII use of the 5.9 GHz band could cause harmful co-channel, adjacent channel, and out-of-band interference to DSRC services. This interference would degrade DSRC V2V and V2I communications, make it impossible to confidently develop new latency-sensitive safety and other applications requiring high spectrum availability, and call into question the viability of the U.S. Department of Transportation's and auto industry's shared vision for connected vehicles. The Alliance and Global have initiated dialog with advocates of 5.9 GHz U-NII use to discuss these concerns, with the hope of achieving assurances that through bench and field testing and analysis, and additional public consultation, the interference issues discussed herein can be resolved. We stand ready to work with the Commission and other stakeholders as this proceeding evolves to address these concerns, but it is important that the Commission continue to preserve the dedicated DSRC spectrum to maximize the potential of this very promising technology.

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I. INTRODUCTION

The Alliance of Automobile Manufacturers, Inc. (the "Alliance")[1] and the Association of Global Automakers, Inc. ("Global"),[2] which together represent the manufacturers of approximately ninety-nine percent of all cars and light trucks sold in the United States,[3] submit these comments in response to the Notice of Proposed Rulemaking ("NPRM") issued by the

[1] The Alliance is an association of twelve of the world's leading car and light truck manufacturers, including BMW Group, Chrysler Group LLC, Ford Motor Company, General Motors Company, Jaguar Land Rover, Mazda, Mercedes-Benz USA, Mitsubishi Motors, Porsche, Toyota, Volkswagen Group of America, and Volvo Cars. *See* Alliance of Automobile Manufacturers, Members, http://www.autoalliance.org/about-the-alliance/overview.

[2] Global Automakers represents international motor vehicle manufacturers, original equipment suppliers, and other automotive-related trade associations. Our members include American Honda Motor Co., Aston Martin Lagonda of North America, Inc., Ferrari North America, Inc., Hyundai Motor America, Isuzu Motors America, Inc., Kia Motors America, Inc., Maserati North America, Inc., McLaren Automotive Ltd., Nissan North America, Inc. Peugeot Motors of America, Subaru of America, Inc., Suzuki Motor of America, Inc., and Toyota Motor North America, Inc. *See* Global Automakers, Members, http://www.globalautomakers.org/members.

[3] *See* Auto Sales, Market Data Center, Wall St. J., May 1, 2013, http://online.wsj.com/mdc/public/page/2_3022-autosales.html#autosalesE.

Federal Communications Commission ("Commission") in the above-captioned proceeding.[4] The NPRM seeks comment on, *inter alia*, making spectrum in the 5.850-5.925 GHz band ("5.9 GHz band") available for Unlicensed National Information Infrastructure ("U-NII") use.[5]

The 5.9 GHz band is allocated for Intelligent Transportation Systems ("ITS"), which utilize Dedicated Short Range Communications Service ("DSRC") systems. DSRC systems, including "safety-of-life"[6] vehicle-to-vehicle ("V2V") and vehicle-to-infrastructure ("V2I") systems, are authorized to operate in the 5.9 GHz band on a primary basis.[7] The Alliance and Global are the main trade associations representing the interests of automobile manufacturers that are developing, testing, and validating 5.9 GHz band DSRC technology.

As discussed below, the Commission should proceed with extreme caution as it considers the substantial technical, policy, economic, and practical challenges to allowing U-NII use of the

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[4] Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band, ET Docket No. 13-49, *Notice of Proposed Rulemaking*, 28 FCC Rcd 1769 (2013) ("*NPRM*").

[5] *Id.* ¶¶ 2, 75.

[6] The Commission has established a priority framework for DSRC communications, explaining that "DSRC communications involving imminent safety-of-life," including, "*e.g.*, vehicle-to-vehicle collision avoidance—must have access priority over all other DSRC communications." Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850-5.925 GHz Band (5.9 GHz Band), Amendment of Parts 2 and 90 of the Commission's Rules to Allocate the 5.850-5.925 GHz Band to the Mobile Service for Dedicated Short Range Communications of Intelligent Transportation Services, WT Docket No. 01-90, ET Docket No. 98-95, RM-9096, *Report and Order*, 19 FCC Rcd 2458, 2475 ¶ 32 (2004) ("*2003 Licensing and Service Order*"). The International Telecommunication Union Constitution recognizes that "safety-of-life" communications must be given "absolute priority." Int'l Telecomm. Union Constitution Article 40 – Priority of Telecommunications Concerning Safety of Life, *available at* http://www.itu.int/net/about/basic-texts/constitution/chaptervi.aspx. Moreover, Congress created the Federal Communications Commission, in part, "for the purpose of promoting safety of life and property through the use of wire and radio communications." 47 U.S.C. § 151.

[7] *NPRM* ¶ 92 (citing 47 C.F.R. § 2.106 Table of Frequency Allocations—Non-Federal Government footnote NG-160).

5.9 GHz band. Although the Alliance and Global understand the Commission's goal of providing additional spectrum to support wireless broadband services and are fully committed to working with the proponents of U-NII use to evaluate the prospects for coexistence with DSRC, that goal should not be elevated above the goal of facilitating the "safety-of-life" systems for which DSRC technology is intended. The NPRM raises extremely troubling concerns that could undermine the efforts of government and private sector stakeholders to deploy "safety-of-life" DSRC services in the 5.9 GHz band. As explained in more detail below, U-NII use of the 5.9 GHz band could cause harmful co-channel, adjacent channel, and out-of-band interference to DSRC services in numerous ways that would significantly reduce or eliminate the anticipated benefits associated with vehicle-based safety communication systems.

The Commission should not allow U-NII use of the 5.9 GHz band unless a set of rules can be developed and shown, through rigorous bench and field testing, to protect 5.9 GHz "safety-of-life" DSRC systems from harmful interference. Moreover, before any rules allowing 5.9 GHz U-NII use based on such testing are promulgated, the Commission should seek formal public comment on such rules to ensure that they adequately protect DSRC services.

II. SUMMARY

A. DSRC and Other Connected Vehicle Technologies Will Provide Significant Public Interest Benefits

DSRC and other connected vehicle technologies are poised to provide significant public safety, traffic management, environmental, and other benefits, and become central components of the nation's twenty-first century highway transportation system. DSRC is a wireless technology that uses the 5.9 GHz band for active vehicle safety systems, which may help prevent or mitigate traffic accidents by providing drivers with greater situational awareness of nearby vehicles and roadway conditions (through audible/visual warning systems), and may in the future intervene in emergencies (by temporarily taking control of the vehicle braking/steering). It includes both V2V and V2I communications.

V2V is the wireless exchange of data between vehicles, allowing vehicles to sense each other and potential threats and hazards, while also providing feedback to help avoid or mitigate crashes.[8] V2I complements V2V by allowing the exchange of data between vehicles and roadway infrastructure, supplementing the public safety advantages of V2V and providing additional real-time traffic management and road condition information. In this way, mobility-based applications will increase the everyday utility of V2I and V2V systems for the general driving public. Together, these technologies have the potential to provide significant safety benefits to motorists; however, their tremendous promise is threatened by the unintended consequences of the Commission's NPRM and the potentially life threatening impact of U-NII operations in the 5.9 GHz band.

B. DSRC Technologies in the 5.9 GHz Band Are at an Advanced Stage of Development and Are Near Widespread Deployment

Automakers have invested significant time and resources into DSRC. Technologies that utilize DSRC in the 5.9 GHz band are, in fact, at an advanced stage of development and are nearing readiness for deployment.[9] Message set standards to exchange DSRC information between vehicles manufactured by different automakers have been developed through the

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[8] U.S. Department of Transportation ("USDOT"), Research and Innovative Technology Administration ("RITA"), Vehicle-to-Vehicle (V2V) Communications for Safety, http://www.its.dot.gov/research/v2v.htm ("RITA: V2V Communications").

[9] Intelligent Transportation Society of America, http://www.itsa.org/advocacy/safety-and-connected-vehicles-.

Society of Automotive Engineers ("SAE") standards-setting process.[10] An IEEE standard, 802.11p, the foundation of which includes the initial Wi-Fi standard, has also been developed for use in DSRC radio devices.[11] In addition, six agencies within the U.S. Department of Transportation ("USDOT") (the National Highway Traffic Safety Administration ("NHTSA"), Research and Innovative Technology Administration ("RITA"), Federal Highway Administration ("FHWA"), Federal Motor Carrier Safety Administration ("FMCSA"), Federal Transit Administration ("FTA"), and the Federal Railroad Administration) are currently conducting a large-scale Connected Vehicle Safety Pilot Program with private industry partners in Ann Arbor, Michigan to validate the effectiveness of DSRC technology and further study how drivers respond to the safety applications enabled in their vehicles.[12] The data collected through this pilot program will serve as the basis for a NHTSA decision expected later this year that could mandate the deployment of connected vehicle technologies in all new vehicles, facilitate voluntary installation of wireless devices in new cars, or spur further research and development.[13]

DSRC-enabled V2V technologies are also being deployed internationally. In Europe, ITS using DSRC will be deployed starting in 2015 on an opt-in basis,[14] and there are similar

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[10] *See* SAE International, DSRC Implementation Guide (2010), *available at* http://www.sae.org/standardsdev/dsrc/DSRCImplementationGuide.pdf ("SAE DSRC Implementation Guide").

[11] *Id.* at 23.

[12] USDOT, RITA, Connected Vehicle Safety Pilot Program, http://www.its.dot.gov/factsheets/pdf/SafetyPilot_final.pdf.

[13] *Id.*

[14] *See* Press Release, Car 2 Car Communications Consortium, European vehicle manufacturers working hand in hand on development of cooperative Intelligent Transport Systems and Services (C-ITS) (Oct. 10, 2012) *available at* http://www.car-to-

initiatives in Japan, Korea, and China.[15] ABI Research estimates that government mandates and automotive industry initiatives will lead to the widespread adoption of connected vehicle technologies, pushing the penetration rate to 61.8 percent by 2027.[16]

C. Allowing U-NII Use of the 5.9 GHz Band Could Cause Harmful Interference to and Undermine the Viability of "Safety-of-Life" DSRC Operations

Although the NPRM seeks comment on the potential use of U-NII devices in the 5.9 GHz band, it is unclear whether any such use of the band is compatible with "safety-of-life" DSRC services and, if so, under what conditions.

DSRC services such as V2V and V2I are "safety-of-life" services that cannot tolerate any interruption, delay, or degradation. Even minor interruptions or degradations of V2V or V2I could result in a failure of DSRC safety applications to help a driver avert preventable vehicle collisions. In 2006, the Commission recognized the importance of "safety-of-life" DSRC services and took the unusual step of designating specific DSRC frequencies (channels 172 and 184) strictly for safety-related communications.[17]

U-NII use of the 5.9 GHz band could cause harmful co-channel, adjacent channel, and out-of-band interference to DSRC services. For example, the bandwidth and power limit

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car.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/downloads/forum08/PressReleases/Press_release_on_MoU.pdf&t=1369177568&hash=e10dbbc1b4f6ba5990d73e5b90ed19fc72b3b436.

[15] ABI Research, V2V Penetration in New Vehicles to Reach 62% by 2027 (2013), http://www.abiresearch.com/press/v2v-penetration-in-new-vehicles-to-reach-62-by-202 ("ABI Research: V2V Adoption").

[16] *Id.*

[17] *See* Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850-5.925 GHz Band (5.9 GHz Band), Amendment of Parts 2 and 90 of the Commission's Rules to Allocate the 5.850-5.925 GHz Band to the Mobile Service for Dedicated Short Range Communications of Intelligent Transportation Services, WT Docket No. 01-90, ET Docket No. 98-95, RM-9096, *Memorandum Opinion and Order*, 21 FCC Rcd 8961, 8963 ¶ 1 (2006) ("*2006 MO&O*").

discrepancies between U-NII and DSRC systems could create substantial detection challenges for U-NII devices. Another likely source of co-channel interference is the certain increase of congestion in the DSRC channels from U-NII devices. These and other interference concerns are discussed in more detail in Section V and the attached Technical Appendix.

Alliance and Global members are currently investing in and developing DSRC services and technologies. If they cannot be absolutely certain that these connected vehicle technologies will be protected against harmful interference from U-NII devices, the potential improvements in road safety enabled by DSRC will never be realized. As discussed below, the full benefits of ITS will only be realized through significant penetration of outfitted vehicles with DSRC equipment. Moreover, automakers will not continue to invest in developing and deploying DSRC systems if DSRC's efficacy is compromised by the operation of U-NII devices in the 5.9 GHz band.

D. It is Imperative that the Commission Await the Results of NTIA's 5.9 GHz Band Study and the Finalization of a U.S. Position on Compatibility Before Proceeding with a Proposal for U-NII Use

Earlier this year, the National Telecommunications and Information Administration's ("NTIA") 5 GHz Report concluded that more analysis is needed to determine whether the 5.9 GHz band can accommodate U-NII operations without causing harmful interference to "safety-of-life" DSRC operations.[18] NTIA is currently conducting additional analysis to determine the implications for DSRC of U-NII use of the band, which NTIA estimates will

[18] Department of Commerce, Evaluation of the 5350-5470 MHz and 5850-5925 MHz Bands Pursuant to Section 6406(b) of the Middle Class Tax Relief and Job Creation Act of 2012 at 5-13 (2013), *available at* http://www.ntia.doc.gov/files/ntia/publications/ntia_5_ghz_report_01-25-2013.pdf ("NTIA 5 GHz Report").

conclude with final recommendations to the Commission in mid-to-late 2014.[19] Additionally, the U.S. is currently developing a position on possible international uses of the 5.9 GHz band for the International Telecommunications Union's ("ITU") 2015 World Radiocommunication Conference ("WRC-15").[20] Before determining whether to allow U-NII use of the 5.9 GHz band, the Commission should await the results of NTIA's study, as well as bench and field testing of any possible prototype U-NII devices designed for use in the 5.9 GHz band, the completion of work by other domestic and international organizations that are studying potential uses of the 5.9 GHz band, and NHTSA's decision later this year regarding the future deployment of DSRC technologies. If, based on this activity, a concrete view is reached on whether and under what circumstances U-NII devices might be able to operate in the 5.9 GHz band without causing harmful interference to DSRC operations, the Commission should seek formal public comment on such view and any proposed rules for U-NII 5.9 GHz band operations. Because V2V and V2I technologies have the potential to improve traffic safety, such a thorough and rigorous review is essential and will allow all stakeholders to evaluate the Commission's proposal.

The Commission's Part 15 rules require that unlicensed spectrum devices not cause harmful interference to licensed services.[21] U-NII devices have not been shown to avoid interfering with licensed DSRC services, nor has there been any testing to date. Consistent with its legal mandate, the Commission should not allow U-NII operations in the 5.9 GHz band unless it is absolutely certain that such use will comport with its Part 15 rules.

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[19] *Id.* at 6-4.

[20] *Id.* at 6-3.

[21] 47 C.F.R. § 15.5.

The Alliance and Global are prepared to work with the Commission, NTIA, advocates of 5.9 GHz U-NII use, and other stakeholders on these issues, and we have already begun such a dialog with proponents of U-NII 5.9 GHz use. However, anything short of a deliberate, data-driven testing process for evaluating U-NII/DSRC compatibility will raise serious concerns regarding the viability of DSRC.

III. DSRC AND OTHER ITS TECHNOLOGIES ARE POISED TO BECOME CENTRAL COMPONENTS OF THE 21ST CENTURY HIGHWAY TRANSPORTATION SYSTEM

From all current indications, DSRC-based connected vehicle technology will be a leading factor in enabling the safe and efficient operation of the highway transportation system for the foreseeable future. With the number of vehicles on U.S. roads continuing to grow but construction of new road capacity likely limited, "smart" vehicles and roadway infrastructure will be necessary to allow the highway system to function in a safe, environmentally sustainable, and efficient manner. USDOT describes the potential for the technology as follows:

> The U.S. Department of Transportation is committed to improving safety and mobility on our nation's roadways. As we look ahead to the next stage of roadway safety in America, connected vehicle technology shows great promise in transforming the way Americans travel. Through wireless technology, connected vehicles ranging from cars to trucks and buses to trains could one day be able to communicate important safety and mobility information to one another that helps save lives, prevent injuries, ease traffic congestion, and improve the environment.[22]

A. DSRC Services Will Improve Automobile Safety by Reducing Crashes

According to data from NHTSA, in 2011 there were 5,338,000 vehicle crashes, accounting for 32,367 deaths and 2,217,000 persons injured. In 2009, traffic fatalities were the

[22] USDOT Connected Vehicle Technology Fact Sheet, http://www.safercar.gov/ConnectedVehicles/pages/resources.html .

leading cause of death for Americans aged 4 and 11-27.[23] DSRC systems have the potential to make America's roadways safer by helping drivers avoid or mitigate crashes.

As discussed above, DSRC involves both V2V and V2I.[24] According to RITA, V2V has the potential to provide significant road safety benefits. V2V technologies exchange "vehicle-based data regarding position, speed, and location (at a minimum)," which "enables a vehicle to: sense threats and hazards with a 360 degree awareness of the position of other vehicles and the threat or hazard they present; calculate risk; issue driver advisories or warnings; or assist in taking pre-emptive actions to avoid and mitigate crashes."[25] USDOT's plan for DSRC includes, ultimately, making all vehicles (including commercial and public transit vehicles) V2V-enabled and capable of communicating with one another. According to NHTSA, these initial exchanges of data will support future generations of active safety applications and systems, which could "enable active safety systems that can assist drivers in preventing approximately 80% of non-impaired driving accidents."[26]

The benefits of V2V are complemented by connectivity between (1) vehicles and infrastructure, and (2) vehicles and consumer portable electronic devices.[27] V2I involves the "wireless exchange of critical safety and operational data between vehicles and highway

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[23] USDOT, National Highway Traffic Safety Administration ("NHTSA"), Traffic Safety Facts: 2011 Data (2013), *available at* http://www-nrd.nhtsa.dot.gov/Pubs/811753.pdf.

[24] *NPRM* ¶ 93.

[25] RITA: V2V Communications.

[26] NHTSA, Connected Vehicles, Vehicle-to-Vehicle (V2V) Communications for Safety, http://www.safercar.gov/ConnectedVehicles/pages/v2v.html.

[27] *Id.*

infrastructure."[28] V2I enables transportation infrastructure to become "smart infrastructure" by using the data exchanged between vehicles and infrastructure elements to recognize high-risk situations before they occur and provide alerts and warnings to drivers. According to RITA, the vision for V2I is to deploy enough V2I-enabled infrastructure "to provide the maximum level of safety and mobility benefits for highway safety and operational efficiency nationwide."[29] According to NHTSA, V2I supplements the safety benefits of V2V and can help prevent another 12 percent of vehicle crashes.[30] In addition to its potential safety advantages, V2I can provide improvements in mobility and environmental benefits "by reducing delays and congestion caused by crashes, enabling wireless roadside inspections, or helping commercial vehicle drivers identify safe areas for parking."[31]

A number of additional V2V and V2I applications are being developed in the U.S. and through complementary work in Europe and Japan. These applications (which, like the other V2V and V2I applications mentioned above, require extremely low-latency, high availability communications) include:

- Pre-crash safety communications to reduce injuries when a crash is unavoidable;
- Systems to address violations of traffic control devices (traffic lights and stop signs) and curve-speed-warnings to prevent roadway departures;
- Extensions to road users, such as pedestrians, motorcycle riders, bicyclists, and others through smart phones or other wireless consumer devices;

[28] USDOT, RITA, Vehicle-to-Infrastructure (V2I) Communications for Safety, http://www.its.dot.gov/research/v2i.htm ("RITA: V2I Communications").

[29] *Id.*

[30] *Id.*

[31] *Id.*

- Enhancements to currently available systems, such as adaptive cruise control, lane departure prevention, and crash-imminent braking with increased availability, reliability and speed of information; and

- Applications that enable coordination of automated traffic streams.

Because these applications will continue to evolve over time, it is critical that the Commission protect all channels assigned to DSRC against harm or degradation from new U-NII use, and not just the channels currently designated for high-priority safety and public safety use (such as channels 172 and 184).

B. DSRC Services Can Provide Significant Traffic Management Benefits, Further Improving Public Safety

Traffic congestion wastes time and money and causes unnecessary air pollution. In 2011, urban traffic congestion on U.S. roadways led to 5.5 billion hours of travel delay, increased travel times by almost 20 percent, and squandered more than $121 billion – approximately $818 per average commuter.[32] Traffic congestion also slows the movement of commodities by truck, costing $27 billion in wasted fuel in 2011.[33] Traffic accidents are a principal cause of traffic congestion, triggering about 25 percent of traffic congestion problems – second only to bottlenecks.[34] Bad weather, unexpected road construction, poor traffic signal timing, and special events also contribute significantly to traffic congestion.[35]

[32] Texas Transportation Institute, The 2012 Urban Mobility Report at 1, 5 (Dec. 2012), *available at* http://mobility.tamu.edu/ums/report/ ("2012 Urban Mobility Report").

[33] *Id.* at 14.

[34] USDOT, Federal Highway Administration (FHWA), Describing the Congestion Problem, http://www.fhwa.dot.gov/congestion/describing_problem.htm.

[35] *Id.*; *see also* 2012 Urban Mobility Report at 12.

RITA's Applications for the Environment: Real-Time Information Synthesis ("AERIS") program seeks to "generate and acquire environmentally-relevant real-time transportation data, and use these data to create actionable information that support and facilitate 'green' transportation choices by transportation system users and operators."[36] The AERIS program works in conjunction with V2V research efforts to mitigate the negative environmental impacts of surface transportation.[37] RITA is also pursuing Road Weather Connected Vehicle Applications. This program is intended to reduce crash risk due to inclement weather conditions, thereby increasing mobility and reducing road maintenance costs by providing data on real-time road conditions.[38]

Real-time communications between and among vehicles and roadside infrastructure using V2V, V2I, and other DSRC technologies can reduce traffic congestion, shorten travel times, improve traffic flow, and improve traffic signal timing.[39] The most apparent traffic management benefit of DSRC services is derivative – by reducing the number of traffic crashes, as discussed above, DSRC also reduces the incidence of traffic congestion.[40] V2I technologies also transform road infrastructure elements into "smart infrastructure," allowing the exchange of data between infrastructure and vehicles to enable real-time safety warnings, safety message monitoring, and

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[36] USDOT, RITA, Applications for the Environment: Real-Time Information Synthesis (AERIS), http://www.its.dot.gov/aeris/.

[37] *Id.*

[38] *See* USDOT, RITA, Road Weather Connected Vehicle Applications, http://www.its.dot.gov/connected_vehicle/road_weather.htm.

[39] RITA: V2V Communications; *see also NPRM* ¶ 92.

[40] *See generally* Section III. A, *supra*.

driver information updates related to local traffic disruptions or severe weather.[41] Utilizing the wealth of information communicated between vehicles and infrastructure on existing roadways, DSRC services improve traffic flow and enable more effective traffic management algorithms in traffic signals, easing other common sources of congestion.[42]

C. DSRC Services Can Provide Significant Environmental Benefits

Traffic congestion also causes massive environmental impacts. According to the Environmental Protection Agency, transportation is the second-largest emitting sector of carbon dioxide (CO_2) greenhouse gases, contributing to 32 percent of CO_2 emissions in 2010, with the majority of those emissions coming from vehicles operated for personal use.[43] A significant amount of these emissions come from cars and trucks going nowhere. In 2011, cars and trucks idling or inching along in bumper-to-bumper traffic pumped 56 billion pounds of CO_2 into the atmosphere, while wasting approximately 2.9 billion gallons of fuel.[44] In addition to greenhouse gas reduction, traffic congestion mitigation strategies have the potential to provide significant reductions in conventional pollutant (e.g., hydrocarbons, carbon monoxide, oxides of nitrogen, diesel particulate, etc.) emissions.[45] To the extent that DSRC services can reduce crashes,

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[41] RITA: V2I Communications.

[42] *Id.*; 2012 Urban Mobility Report at 19 (discussing "prominent types of operational treatments," including programs studied by USDOT's Intelligent Transportation Systems Joint Program Office, and the potential benefits of these treatments).

[43] U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010 at ES-4, ES-8 (Apr. 2012), *available at* http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2012-Main-Text.pdf.

[44] 2012 Urban Mobility Report at 1, 13.

[45] *See* USDOT, FHWA, Air Quality programs, http://www.fhwa.dot.gov/environment/air_quality/.

improve traffic flow, or reduce the time drivers spend in stop-and-go traffic, they will also provide corresponding benefits for the environment.

D. Congress and the Commission Have Long Recognized the Transportation Benefits of Interoperable ITS and DSRC Services

Over the past twenty years, Congress has authorized billions of dollars for ITS research and development. In addition, years of work by Congress, the Commission, USDOT, and the private sector have laid the groundwork for the coming connected vehicle deployments.

Congress. Congress created the ITS program in 1991 with enactment of the Intermodal Surface Transportation Efficiency Act of 1991 ("ISTEA"), which authorized $659 million for Federal research, development, and testing, and implementation of ITS.[46] Congress has continued to fund the ITS program through additional authorizations in 1998 ($1.3 billion through fiscal year 2003)[47] and 2005 ($110 million annually through fiscal year 2009).[48] In addition, in 2012 Congress enacted the Moving Ahead for Progress in the 21st Century Act ("MAP-21"), which authorized an additional $200 million for ITS research and deployment for fiscal years 2012 and 2013 and directed the Secretary of Transportation "to expedite … the development and deployment of intelligent transportation systems," carry out research and development and testing of ITS-enabled vehicles and infrastructure, and submit a report in 2015

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[46] *See* Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), Pub. L. 102-240, § 6059, 105 Stat. 1914 (1991).

[47] *See* Transportation Efficiency Act for the 21st Century (TEA-21), Pub. L. 105-178, 112 Stat. 107 (1998).

[48] *See* Safe Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, Pub. L. 109-59, 119 Stat. 1144 (2005).

assessing the status of ITS systems and recommending a path for implementing DSRC technologies.[49]

In creating the ITS program, Congress found that "intelligent vehicle highway systems represent the best near-term technology for improving surface transportation for public benefit by providing equipment which can improve highway traffic flow and provide for enhanced safety."[50] In 1998, Congress explained that the investments authorized by ISTEA:

> demonstrated that intelligent transportation systems can mitigate surface transportation problems in a cost effective manner; and continued investment in architecture and standards development, research and systems integration is needed to accelerate the rate at which intelligent transportation systems are incorporated into the national surface transportation network, thereby improving transportation safety and efficiency and reducing costs and negative impacts on communities and the environment.[51]

Moreover, as RITA explains, the ITS program "was designed to facilitate deployment of technology to enhance the efficiency, safety, and convenience of surface transportation, resulting in improved access, saved lives and time, and increased productivity."[52]

The Commission. The Commission has also recognized the importance of DSRC for "safety-of-life" and public safety communications. In 2003, the Commission adopted licensing and service rules for DSRC technologies in the 5.9 GHz band to facilitate the development of

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[49] *See* Moving Ahead for Progress in the 21st Century Act, Pub. L. 112-141, 126 Stat. 405 §§ 53001-53006 (2012).

[50] ISTEA, §6009(a)(6).

[51] TEA-21, § 5202(1)-(2).

[52] USDOT, RITA, Intelligent Transportation Systems Joint Program Office, http://www.its.dot.gov/faqs.htm. *See also 2003 Licensing & Service Order* ¶ 17 (adopting licensing and service rules for DSRC services in the 5.9 GHz band and stating that Congress' goal for the national ITS program was to "increase the safety and efficiency of the nation's surface transportation system").

new and innovative services.[53] The Commission's 2003 Order also adopted a band plan for DSRC services, creating seven, 10 megahertz channels in the band, consisting of one control channel (Channel 178) and six service channels (Channels 172, 174, 176, 180, 182, and 184), and one 5 MHz channel to be held in reserve.[54] In addition, the 2003 Order showed a keen understanding of the importance of DSRC services for "safety-of-life" and public safety communications by establishing a priority framework for those communications in the 5.9 GHz band control channel.[55]

The Commission subsequently amended the 5.9 GHz band plan in 2006 with "safety-of-life" and public safety applications in mind.[56] The 2006 Order designated Channel 172 exclusively for "vehicle-to-vehicle communications for accident avoidance and mitigation, and safety of life and property applications," and designated Channel 184 exclusively for "high-power, longer-distance communications to be used for public safety applications involving safety of life and property, including road intersection collision mitigation."[57] In designating the exclusive-use channels, the Commission explained that "[a]lthough the Commission has long recognized that shared use of spectrum promotes spectrum efficiency, there are cases in which public safety concerns dictate exclusive use of frequencies," and concluded that DSRC constituted such a case because "the delay associated with shared use of a time-critical DSRC

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[53] *2003 Licensing and Service Order* ¶ 1.

[54] *Id.* ¶¶ 25-29.

[55] *Id.* ¶¶ 30-34.

[56] *See 2006 MO&O*.

[57] *Id.* ¶ 1.

channel could be literally life-threatening in the context of collision avoidance."[58] Such was the situation in 2006, and it remains so today.

Industry Efforts. Following the allocation of the 5.9 GHz band for use by DSRC systems, the Intelligent Transportation Society of America ("ITS America"), which at the time was the USDOT-selected Federal Advisory Committee on ITS matters, began holding industry and stakeholder meetings to develop a consensus on interoperability in the deployment of DSRC services.[59] In October 2000, ITS America filed a report with the Commission that addressed licensing and service rules, as well as deployment strategies for DSRC. In May 2002, the American Society for Testing and Materials Subcommittee E17.51 ("ASTM") (which had been working with the FHWA) selected the ASTM-DSRC E2212-013 Standard ("ASTM-DSRC Standard") as the standard for DSRC-based ITS applications in the 5.9 GHz band.[60] Finally, in 2010, the IEEE 802.11p standard was approved and will be "used as the groundwork for DSRC."[61]

IV. DSRC CONNECTED VEHICLE TECHNOLOGY IS AT AN ADVANCED STAGE OF DEVELOPMENT, AND THE COMMISSION SHOULD PROCEED CAUTIOUSLY TO AVOID DISRUPTING ITS DEPLOYMENT

As discussed above, USDOT, the Commission, and industry stakeholders have laid the foundation for the widespread launch and adoption of DSRC-connected vehicle technologies. Working together, these parties have established standards and protocols for V2V and V2I technologies, established service rules and power levels for their operation, and designated

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[58] *Id.* ¶ 16.

[59] *2003 Licensing and Service Order* ¶¶ 6, 9.

[60] *Id.* ¶ 9.

[61] SAE DSRC Implementation Guide at 23.

specific channels for their use. This tremendous industry and government effort was necessary to ensure that vehicles and equipment manufactured by different companies will be able to communicate with each other and with DSRC infrastructure, no matter where in the U.S. the need arises.

Federal agencies, vehicle and equipment manufacturers, standards-setting organizations, and other stakeholders are in the midst of numerous research initiatives designed to further develop and implement DSRC.[62] NHTSA, for example, is currently researching DSRC V2V to determine whether to adopt regulations on the future of connected vehicle technology.[63] These regulations could lead to mandated deployment of connected vehicle technologies in new vehicles or voluntary installation of V2V and V2I devices in new cars.[64] NHTSA is expected to reach a decision on this "priority project" in 2013.[65] Other research projects include efforts to globally harmonize connected vehicle technologies,[66] understand and plan for potentially distracting effects of DSRC technologies on drivers,[67] further refine the underlying technology platform,[68] implement certification requirements and mechanisms to protect consumer safety,

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[62] USDOT, Intelligent Transportation Systems ("ITS"), Connected Vehicle Research, http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm.

[63] *See* NHTSA, Vehicle Safety and Fuel Economy Rulemaking and Research Priority Plan 2011-2013 at 7 (2011), *available at* http://www.regulations.gov/contentStreamer?objectId=0900006480e78ab2&disposition=attachment&contentType=pdf.

[64] ABI Research: V2V Adoption.

[65] *Id.* at 7.

[66] USDOT, ITS, Human Factors Research, http://www.its.dot.gov/connected_vehicle/human_factors.htm.

[67] USDOT, ITS, Harmonization of International Standards and Architecture around the Vehicle Platform, http://www.its.dot.gov/research/harmonization.htm.

[68] USDOT, ITS, Vehicle to Vehicle Communications Systems Engineering, http://www.its.dot.gov/research/systems_engineering.htm.

security, and privacy,[69] and develop "connected vehicle test beds" to provide real-world, operational test beds for DSRC testing and certification activities.[70]

DSRC systems are already being tested in real-world environments. USDOT and the University of Michigan Transportation Research Institute are in the middle of a year-long Safety Pilot Model Deployment ("Safety Pilot") to "test the effectiveness of connected vehicle safety applications for reducing crashes, and show how drivers respond to these technologies while operating a vehicle in a real-world, multi-modal environment."[71] The Safety Pilot began with clinics that tested V2V technologies with hundreds of drivers in controlled environments across the country, and has now entered its second phase, the Safety Pilot Model Deployment.[72] The Safety Pilot Model Deployment utilizes a test site with multi-modal traffic and a high concentration of V2V-equipped vehicles, including a limited set of V2I technologies at intersections with traffic signals.[73] This deployment involves more than 2,800 vehicles, including a mix of cars, trucks, and buses (driven by volunteers from the general public who reflect the general driver population), traveling over 73 lane-miles of freeways and city streets in Northeast Ann Arbor, Michigan.[74] The empirical data collected through the Safety Pilot will "present a more accurate, detailed understanding of the potential safety benefits of these

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[69] USDOT, ITS, Connected Vehicle Certification, http://www.its.dot.gov/connected_vehicle/connected_vehicle_cert.htm.

[70] USDOT, ITS, The Connected Vehicle Test Bed, http://www.its.dot.gov/testbed.htm.

[71] University of Michigan Transportation Research Institute, Safety Pilot, http://www.safetypilot.us/.

[72] University of Michigan Transportation Research Institute, Program Overview, http://www.safetypilot.us/program-overview.html ("UMTRI Program Overview").

[73] *Id.*

[74] University of Michigan Transportation Research Institute, How It Works, http://www.safetypilot.us/how-it-works.html.

technologies," as well as their non-safety benefits "relating to mobility and environmental impacts."[75]

Research is also underway to assess how these important DSRC services would be affected by U-NII use of the 5.9 GHz band. NTIA, for example, in conjunction with USDOT, is conducting a quantitative evaluation of the suitability of the 5.9 GHz band for U-NII device operations, and the implications such operations would have for DSRC.[76] Its activity will involve defining the technical characteristics of DSRC systems and U-NII device deployment and technical parameters, conducting simulations under various sharing scenarios, developing initial recommendations related to the suitability of the 5.9 GHz band for U-NII operations, performing laboratory and field measurements, and ultimately finalizing recommendations to the Commission and for international study.[77] As noted above, NTIA is expected to finalize its recommendations to the Commission between July 2014 and December 2014.[78]

The Commission must ensure that all of this promising activity is not undermined or nullified by an ill-informed decision to allow U-NII use of the 5.9 GHz band. Indeed, the fact that the Commission has sought comment on a broad proposal to allow U-NII use of the band has already chilled the discussion of potential investment in DSRC equipment.[79] If previous

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[75] UMTRI Program Overview. The Safety Pilot assumes that there will be no U-NII device use in the 5.9 GHz band.

[76] NTIA 5 GHz Report at 6-3, 6-4; *see also* David Shepardson, *DOT Urges FCC not to award wireless spectrum without testing*, The Detroit News, May 7, 2013 *available at* http://www.detroitnews.com/article/20130507/AUTO01/305070427/1361/DOT-urges-FCC-not-to-award-wireless-spectrum-without-testing.

[77] *Id.* at 6-4.

[78] *Id.*

[79] *See* Paul Kirby, *Rohde Bemoans Impact of 5 GHz NPRM on Connected-Vehicle Firm*, TR Daily, May 20, 2013 (quoting Greg Rohde on behalf of Savari Networks, a developer of DSRC equipment, that the

experience with new wireless services is any indication, some level of marketplace anxiety will continue until the Commission makes clear its commitment to adequately protect DSRC services.

Such anxiety is not surprising given the experience of other primary users of the 5 GHz band that have been affected by U-NII operations. The NPRM noted that a few years ago NTIA field testing determined that the operation of U-NII devices in the 5.60-5.65 GHz band was causing harmful interference to Terminal Doppler Weather Radar ("TDWR"), which holds primary status in the band.[80] The interference was largely caused by U-NII devices that had been modified to operate outside their authorized spectrum bands.[81] While the interference from U-NII devices was first discovered in 2009, a resolution to the problem has not yet been reached.[82] Without assurance from the Commission that harmful interference to DSRC systems will not occur as a result of expanded U-NII operations, there could be a reduction in research and development and a further chilling of investment in DSRC systems, delaying and possibly foreclosing the widespread deployment of V2V and V2I technologies.

V. THE COMMISSION SHOULD NOT ALLOW U-NII USE OF THE 5.9 GHZ BAND UNLESS IT CAN BE OBJECTIVELY DEMONSTRATED THAT SUCH USE WILL NOT INTERFERE WITH DSRC SYSTEMS

The Alliance and Global are concerned that DSRC services could be severely compromised by new unrestricted U-NII use of the 5.9 GHz band. The disruption of DSRC

Commission's proposal to allow U-NII devices to share the 5.9 GHz band had a "chilling effect" on discussions with potential investors).

[80] *NPRM* ¶ 8.

[81] *Id.* ¶ 9.

[82] *Id.* ¶ 10.

operations in the 5.9 GHz band would cripple the "safety-of-life" and other DSRC applications used for ITS – and threaten DSRC's viability. Prior to any final action in this proceeding, the Commission should demonstrate, through rigorous field and bench testing, that U-NII use of the band will not interfere with DSRC systems, and seek formal public comment on any proposed rules for U-NII 5.9 GHz use developed based on such testing. In that way, all relevant stakeholders will be able to evaluate the potential impact of the Commission's proposal.

A. Interference Would Significantly Undermine the Safety Benefits of DSRC Systems and Threaten DSRC Deployment

1. Interference to V2V and V2I Services Poses Significant Safety Risks

As the Commission has previously recognized, V2V and V2I applications are "exceptionally time-sensitive and should not be conducted on potentially congested channels."[83] This was precisely the Commission's rationale for designating DSRC channels 172 and 184 exclusively for "safety-of-life" and public safety applications, such as vehicle collision avoidance and mitigation.[84] In fact, "safety-of-life" applications such as V2V and V2I cannot tolerate even infrequent instances of harmful interference. The NPRM observed that applications that use V2V and V2I "need secure, wireless interface dependability in extreme weather conditions, and short time delays; all of which are facilitated by DSRC."[85] Any excessive congestion or interference could lead to increased latency, lost packets of data, or

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[83] *2006 MO&O* ¶ 16.

[84] *Id.* ¶¶ 16-17.

[85] *NPRM* ¶ 93.

degraded security functions, significantly decreasing the safety benefits of such applications.[86] If signals are degraded or interrupted, or transmissions are not received, vehicle collisions that could have been prevented may occur.

Recognizing these risks, the Commission took the unusual step of designating specific DSRC frequencies (channels 172 and 184) strictly for safety-related communications.[87] In doing so, the Commission found that "vehicle-to-vehicle collision avoidance and mitigation applications are exceptionally time-sensitive and should not be conducted on potentially congested channels."[88] The Commission reasoned that DSRC public safety applications fall within that class of "cases in which public safety concerns dictate exclusive use of frequencies" because "the delay associated with shared use of a time-critical [DSRC] channel could be literally life-threatening in the context of collision avoidance."[89] Even a delay of milliseconds[90] – while the DSRC system electronically identified and executed the priority event – "could result in an otherwise avoidable vehicular collision."[91] Because DSRC is extremely latency-sensitive,

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[86] John Maddox, University of Michigan Transportation Research Institute, ITS Spectrum Sharing? – a common sense approach at 9 (Apr. 2013) (included as Attachment 1).

[87] *2006 MO&O* ¶ 16.

[88] *Id.*

[89] *Id.*

[90] A millisecond is one – one thousandth (1/1,000) of a second. 1,000 milliseconds comprise one second. Motor vehicle crashes typically occur over a 100 to 150 millisecond interval. To gain an appreciation of the duration of a typical crash event, consider that light takes approximately 134 milliseconds to travel the circumference of the earth at its equator (a distance of approximately 40,000 kilometers or 25,000 miles) or that the average duration of a single human eye blink is between 100 and 400 milliseconds (see http://bionumbers.hms.harvard.edu/bionumber.aspx?s=y&id=100706&ver=0).

[91] *Id.*

any interference from U-NII devices will degrade DSRC performance and could be catastrophic for drivers.[92]

2. Potential Interference to V2V and V2I Services Will Undermine Their Deployment

The real safety benefits of V2V "can only be realized when a sufficiently large part of the installed vehicle base is connected."[93] The Alliance and Global members have worked (and continue to work) closely with federal agencies and other stakeholders to research and develop interoperable DSRC services and technologies, devoting substantial resources to these potentially life-saving applications. In its 2003 Order, the Commission explained that to accomplish the safety and efficiency goals of DSRC-based ITS applications, USDOT envisioned DSRC On Board Units ("OBUs") in every vehicle working with DSRC Road Side Units ("RSUs") embedded within the transportation infrastructure.[94] Because OBUs and RSUs are designed, developed, and manufactured by different automakers and other companies, standards-based interoperability is vital to the viability of DSRC equipment and services. To enable these communications, all DSRC equipment must be capable of communicating on the same frequency and in the same language, include security features that ensure trustworthy communications, and

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[92] *See* Technical Appendix at 1.3.2 (explaining that U-NII devices operating in the 5.9 GHz band can cause significant interference to the reception of packets carrying safety and other communications. This interference could lead to an unknown and potentially very high rate of inter-packet gaps ("IPG") and packet error rate ("PER"), which would degrade the ability of the vehicle to perform real-time situational awareness and tracking of nearby vehicles and render it unable to provide timely safety warnings of an imminent collision).

[93] *2006 MO&O* ¶ 16.

[94] *2003 Licensing and Service Order* ¶ 14.

manage channel loading to ensure workable message frequencies and power levels.[95] Uncontrolled extraneous signals, such as those from U-NII devices, will therefore be problematic.

If interference to V2V and V2I services or congestion in the 5.9 GHz band minimizes or negates their potential safety benefits, consumers and government regulatory agencies are likely to reject the services. Consumer rejection, in turn, would undermine the development and deployment of these DSRC technologies, making it doubtful that the potentially revolutionary breakthroughs in vehicle and road safety enabled by DSRC will ever be realized. To promote continued investment, interoperability, and widespread consumer adoption, the Commission must ensure that connected vehicle technologies remain viable and not threatened by harmful interference. Without such assurance, the promise of connected vehicle technologies will be unfulfilled.

Finally, significant planning and engineering development has already taken place in reliance on the existing 5.9 GHz band spectral environment. For example, prior to the release of the NPRM, DSRC channel congestion concerns were being addressed based on the assumption that no U-NII devices would be operating in or near the band. Members of the Alliance and Global have invested tens of millions of dollars developing their interoperable DSRC systems in reliance upon the existing spectral environment, and changing that environment so dramatically at this stage would pose severe technical and financial challenges.[96] Moreover, specific changes

[95] As the Commission recognized, "[w]ithout an interoperability standard that enables units to communicate with one another regardless of location, equipment used, or the license, the overall effectiveness of the national DSRC operations would be drastically reduced." *Id.* ¶ 14.

[96] *See* Shepardson, *supra* note 76 (noting since 2005 automakers and governments have spent approximately $130 million researching and testing connected vehicle technologies).

to the DSRC service rules aimed at facilitating compatibility with U-NII use of the 5.9 GHz band would require the Commission to commence a separate rulemaking proceeding, which would create significant uncertainty regarding DSRC's operating environment and, ultimately, its time-to-market.

B. U-NII Use of the 5.9 GHz Band Poses a Significant Interference Threat to DSRC Systems and Road Safety

U-NII use of the 5.9 GHz band could cause harmful co-channel, adjacent channel, and out-of-band interference to DSRC services. As Deputy Transportation Secretary John Porcari has explained, it is unknown whether the Commission's spectrum sharing proposal "will meet DOT's safety requirements and support existing technical standards."[97] Several key interference possibilities are discussed briefly below, and in more detail in the attached Technical Appendix ("TA"). Since applications will continue to evolve over time, it is critical that the Commission protect all channels assigned to DSRC against degradation from new U-NII use. To do otherwise would limit future innovations in the band.

1. U-NII Devices in the 5.9 GHz Band Could Cause Harmful Co-Channel Interference

Detection Issues Due to Channel Size Disparities. One potential cause of co-channel interference is the bandwidth discrepancy between U-NII and DSRC technologies. This discrepancy could create lower layer sensing conflicts between the two operations.[98] As IEEE 802.11 Wi-Fi devices, U-NII devices operate based on 20 MHz wide (or wider) channels, while DSRC is licensed and designed for use over 10 MHz channels. Because current Wi-Fi devices

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[97] *Id.*

[98] *See* Technical Appendix at 1.4.1.

have not been designed to detect 10 MHz channel widths, they would need to be modified (to be capable of verifying that two or more DSRC channels are clear simultaneously) in order to detect DSRC packets and avoid interfering with the DSRC transmissions. Such a redesign would require significant testing both in the laboratory and field to verify its efficacy.

Even if U-NII transmitters were able to achieve the difficult task of simultaneously monitoring two or more DSRC channels, the nomadic nature of vehicle traffic raises questions whether U-NII devices could avoid interfering with DSRC systems. DSRC V2V systems are constantly in motion and do not continuously transmit, which creates significant detection challenges for U-NII devices.[99] Moreover, the absence of DSRC transmissions at any given time or place has little bearing on the probability that DSRC transmissions will occur in the future. When a quiet DSRC device initiates a transmission, a U-NII device must not only detect it in mid-operation, but must instantaneously vacate the channel. This requires the U-NII device to continually monitor the channel on which it is transmitting, which is difficult.

If U-NII devices cannot detect DSRC signals, they will transmit at the same time as DSRC safety messages, causing harmful interference and disrupting, delaying, or degrading the delivery of the DSRC packets with consequential safety implications.[100] In such instances, significant sequences of DSRC packets supporting crash-avoidance safety applications could become unreadable, rendering DSRC "safety-of-life" systems ineffective when called upon.[101]

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[99] NTIA 5 GHz Report at 5-11.

[100] *See* Technical Appendix at 1.5.2 (it is possible that a DSRC channel could be detected by a U-NII device as "clear" at a time when DSRC vehicles are just coming into range. The subsequent U-NII transmission could then unknowingly disrupt DSRC transmissions).

[101] *See id.* at 1.4.3.

Power Limit Disparities and Sensing Concerns. Another potential cause of co-channel interference to DSRC systems from U-NII devices is the disparity in power levels between U-NII devices and DSRC applications. Existing U-NII 5 GHz signal detection technology was not developed to detect DSRC signals, but was instead designed to detect high-power radar signals. It is unclear whether existing U-NII signal detection technology can be viably modified to detect transient-low power DSRC signals.[102]

Currently, V2V safety applications operate at a power range of 18-20 dBm EIRP.[103] The NPRM proposed to allow U-NII devices to operate in the 5.9 GHz band at significantly higher power levels, with a "maximum output power limit [that] is the lesser of 1 Watt and 17 dBm + 10 Log (B) where B is 26 dB emission bandwidth."[104]

The prospect of asymmetrical sensing is a major concern. Because U-NII devices are likely to operate at considerably higher power levels than are DSRC applications, the U-NII devices may be unable to "hear" DSRC operations when higher-powered U-NII devices are also present. As a result, U-NII packets may be sent at the same time that DSRC units attempt to send critical safety communications, causing the DSRC packets to be unreadable by DSRC receiving devices.[105]

Channel Congestion. Another likely source of co-channel interference is the certain increase of congestion in the DSRC channels from U-NII devices. Channel congestion on DSRC V2V safety channels is expected to be common in major metropolitan areas, where significant

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[102] NTIA 5 GHz Report at 5-10, 5-12.

[103] Technical Appendix at 1.4.3.

[104] *NPRM* ¶ 97.

[105] Technical Appendix at 1.4.3.

numbers of deployed U-NII devices are expected. Even if the U-NII devices were running at very low power or operating at significant distance from the vehicles using DSRC, the aggregation of many such U-NII devices would raise the noise floor within the DSRC band, potentially causing harmful interference.[106] Moreover, the Commission will have no control over unlicensed users of the 5.9 GHz band (or even a mechanism for reliably tracking those users), which could result in instances of user misbehavior and disregard for the Commission's rules, causing further harmful interference.

While the NPRM proposes allowing U-NII devices to operate both indoors and outdoors in the 5.9 GHz band,[107] congestion in the band would remain a concern even if the Commission restricted U-NII devices to indoor use. If the Commission adopted an indoor only restriction for 5.9 GHz U-NII devices, it would not be able to exercise the necessary oversight to ensure that the rule was followed. A U-NII device user could simply walk outdoors, making any such restriction superfluous. Further, it is not apparent how radio frequency-permeable openings (*e.g.*, windows) in buildings could be prevented from allowing significant leakage from U-NII devices to the outdoor environment where the transmissions could disrupt DSRC operations.

2. Adjacent Channel and Adjacent Band Operations by U-NII Devices Could Cause Harmful Interference to DSRC Systems

Because U-NII devices operating in or adjacent to the 5.9 GHz band would transmit at significantly higher maximum power levels than DSRC systems, U-NII operations in or near the 5.9 GHz band have the potential to cause harmful interference to sensitive DSRC safety applications.

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[106] *See id.* at 1.4.4, 1.5.6.

[107] *NPRM* ¶ 97.

Adjacent Channel Interference. As detailed above, the Commission specified Channels 172 and 184 for V2V for vehicle collision avoidance and mitigation and public safety applications. These channels were set aside for specific uses in order to separate "safety-of-life" services from other, higher-powered DSRC operations. The Commission's proposal to permit U-NII devices to operate in the 5.9 GHz band would allow the unlicensed devices to operate at a maximum power level that is significantly higher than the power levels being used for DSRC safety services. This high-powered U-NII use could cause harmful interference to sensitive V2V safety applications, even when U-NII devices are transmitting on an adjacent channel.[108]

Out-of-Band Interference. Finally, even if U-NII devices are not permitted to operate in the 5.9 GHz band, placing U-NII operations in spectrum bands that are immediately or closely adjacent to channels used for V2V safety applications would still have the potential to cause harmful interference. The maximum power levels and antenna gain requirements that the Commission has proposed for U-NII operations[109] increase the likelihood that such operations in adjacent or proximate bands will cause harmful interference to DSRC safety applications.[110]

C. The Commission Should Await the Results of NTIA's Study and Other Efforts Regarding the Compatibility of U-NII Use of the 5.9 GHz Band with DSRC and Seek Public Comment on a Proposal for U-NII 5.9 GHz Use Based on Such Efforts

As discussed above, NTIA's January 2013 report on U-NII use of the 5.9 GHz band raised numerous concerns regarding whether U-NII use of the band could be compatible with

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[108] *See* Technical Appendix at 1.6.1, 1.7-1.7.5.

[109] *See NPRM* ¶ 97 (proposing antenna gain requirement of 6 dBi for non-point to-point systems and 23 dBi for point-to-point systems).

[110] *See* Technical Appendix at 1.6.2.

DSRC use.[111] NTIA identified a number of risk elements to DSRC services associated with U-NII use, arising primarily from the fact that existing U-NII regulations, devices, and technologies were not developed with DSRC in mind.[112] NTIA is in the process of conducting further studies on the suitability of the 5.9 GHz band for U-NII use and plans to submit recommendations to the Commission between July and December 2014.[113] And USDOT officials have said that "thorough, independent, and accurate testing … must be completed before the final decision on sharing the spectrum is made."[114]

In addition to NTIA's domestic work, the United States is further investigating compatibility between U-NII devices and DSRC operations as it develops its position on possible uses of the 5.9 GHz band internationally for the ITU's WRC-15 and other fora.[115] This international work is being performed under the State Department's International Telecommunication Advisory Committee ("ITAC"), which is studying U-NII and incumbent system characteristics to address the risks identified by NTIA's 5 GHz Report and determine whether and under what conditions spectrum sharing might be possible.[116] These studies must be finalized by the end of 2014, coinciding with the finalization of NTIA's study, in preparation for WRC-15. Additionally, other nations are likely to proffer their own studies on uses of the 5.9 GHz band before and at WRC-15.[117]

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[111] NTIA 5 GHz Report at 5-12.

[112] *Id.* at 5-10, 5-11, and 5-12.

[113] *Id.* at 6-4.

[114] Shepardson, *supra* note 76 (quoting Deputy Transportation Secretary John Porcari).

[115] NTIA 5 GHz Report at 6-3.

[116] *Id.*

[117] *Id.*

The Commission should await the results of the NTIA analysis and the conclusion of ITAC's study of interference risks in the 5.9 GHz band, and leverage international work on this issue as well, to develop a fully informed proposal regarding potential U-NII use of the 5.9 GHz band. Once a proposed course of action has been developed, and consistent with the Administrative Procedure Act ("Act"), the Commission should seek formal public comment on such proposal, including any U-NII rules or restrictions that might be envisioned. The Commission should not take premature action now regarding shared use of 5.9 GHz spectrum, as doing so would involve incomplete, inconclusive data regarding the grave risks posed by 5.9 GHz U-NII use to life-saving DSRC technologies.

D. The Alliance and Global Are Prepared to Work With All Stakeholders to Find a Solution to Interference Issues, if Possible

The Alliance and Global have started to engage with advocates of U-NII use of the 5.9 GHz band in an attempt to resolve these very important interference issues. While the Alliance and Global recognize the importance of the Commission's goals to free up additional spectrum for Wi-Fi use and welcome the opportunity to ascertain whether DSRC systems for ITS can coexist with U-NII devices in the band, we are skeptical that the Commission's current plan would effectively protect 5.9 GHz DSRC operations and have indicated as such to U-NII stakeholders. It is the Alliance and Global's view that DSRC, as a licensed service in the 5.9 GHz band and an enabler of "safety-of-life" V2V or V2I systems, should receive significant protection from any U-NII operations in the 5.9 GHz band. As noted previously, current U-NII devices use higher transmit powers and larger channel bandwidths than DSRC. This poses a considerable risk of causing harmful interference to 5.9 GHz DSRC systems.

VI. CONCLUSION

Once deployed, 5.9 GHz band DSRC services for ITS could potentially provide momentous road safety, traffic management, and environmental benefits. These services could support safer, faster, and more environmentally friendly travel on our nation's roadways. However, these benefits could be severely undermined – and potentially extinguished – by harmful interference from new untested U-NII devices in the 5.9 GHz band. The Commission therefore should proceed cautiously and avoid allowing U-NII use of the 5.9 GHz band without first ensuring that no harm to DSRC systems will occur.

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TECHNICAL APPENDIX

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TECHNICAL APPENDIX

1.1 INTRODUCTION

In the United States, the automobile industry (OEMs and their supplier base) has been working with the federal government to develop and deploy connected vehicle systems using spectrum allocated to the Dedicated Short-Range Communications (DSRC) service in the 5.850-5.925 MHz (5.9 GHz) band. Similar efforts are underway in Europe and Japan, where deployment has already begun. In the United States, much of the initial focus has been on crash-imminent safety. The concept is that vehicles would broadcast a "Basic Safety Message," or BSM, to nearby, equipped vehicles. The BSM would contain information on the vehicle's state, such as its position, speed and direction. Vehicles receiving these broadcast messages would then be able to determine if other vehicles were on a trajectory that could lead to a collision. The system depends on the reliable, continuous tracking of vehicles from about a 300-meter range to potential collision points. If a threat were determined, a warning to the driver would be issued and/or a control action to avoid the crash initiated.

According to the most recent National Highway Traffic Safety Administration (NHTSA) data, in 2011 there were 5,338,000 vehicle crashes and 32,367 deaths. In 2009 traffic crashes were the leading cause of death for persons aged 4 and 11-27. The United States Department of Transportation (USDOT) has estimated that DSRC vehicle-to-vehicle (V2V) systems potentially address up to 79% of all vehicle target crashes, 81% of all light-vehicle target crashes, and 71% of all heavy-truck target crashes. [1] USDOT's estimates are currently being refined in a year-long model deployment underway in Ann Arbor, Michigan involving almost 3,000 equipped vehicles, including passenger cars and trucks, transit vehicles and commercial vehicles. NHTSA will combine the estimated benefit information with the estimated costs of widespread deployment, and is expected to make a determination later this year regarding a regulation that could require this system on new vehicles.

It is currently envisioned that all BSMs will be transmitted on a single, 10 MHz DSRC channel and that vehicles will be equipped with a receiver that is dedicated to receiving messages on this channel. However, a single unmanaged channel cannot support large numbers of equipped vehicles, and congestion management standards will be adopted to most effectively utilize the channel capacity.

Based on research underway in the United States and complementary work in Europe and Japan, it is envisioned that the initial DSRC-based V2V crash-imminent safety system will be extended to include other applications that will require additional messages and additional DSRC channels for communication. One of the additional planned uses is support for the security system communications required to establish the necessary trust relationship among V2V and V2I cooperative crash avoidance participants. Other planned applications will offer additional safety, mobility and environmental benefits. These additional applications include both safety and automation applications that, like V2V, require low-latency communication, as well as other mobility and environmental applications that are more latency tolerant. These include:

- Pre-crash safety communications to potentially avoid or mitigate a collision;
- Vehicle-infrastructure communications for safety, including systems to address violations of traffic control devices (traffic lights and stop signs) and curve-speed-warnings to prevent roadway departures;
- Extending the system to vulnerable road users, such as pedestrians, motorcycle riders, bicyclists, and others;
- Extension of adaptive cruise control, lane departure prevention, and crash-imminent braking with increased availability, reliability and speed of information;
- Coordination of automated traffic streams;
- Dynamic information to allow travelers to make informed multi-modal decisions regarding their travel time, travel cost and the environmental impact of their travel decisions; and
- Dynamic information used to better control the traffic system.

1.2 DSRC COOPERATIVE CRASH AVOIDANCE SYSTEM DESCRIPTION

Crash-avoidance systems share a common need: the vehicles on which they operate need to know the locations and motions of all neighboring vehicles. Most crash-avoidance systems deployed today try to learn the state of the neighboring vehicles or roadway by using object detection sensors like radar, laser, or vision looking forward, to the rear, to the right lane and left lane.

By contrast, a cooperative crash-avoidance system develops its knowledge of the vehicle neighborhood by listening to the wireless communications of other vehicles and reciprocates with communications of its own. 5.9 GHz DSRC provides an opportunity for safer driving, and its use in cooperative crash-avoidance systems would play a major role in addressing vehicle crashes where multiple vehicles are involved. Moreover, NHTSA estimates that cooperative crash avoidance systems have the potential to address approximately 80% of vehicle crash scenarios involving unimpaired drivers.

V2V communications technology is a crucial component of the cooperative crash-avoidance system. V2V communications use Global Positioning System (GPS) and DSRC on vehicles to allow vehicles to exchange information with one another in an ad hoc broadcast mode of wireless communication. V2V technology expands a driver's perception horizon and thus enhances roadway safety. It allows the vehicle to "see" nearby vehicles and become aware of roadway conditions (e.g., road works) that the driver cannot see, and provides 360-degree "visibility" at a lower cost than object detection sensors.

Figure 1 – An illustration of V2V communication

DSRC is used for wireless communications in cooperative crash-avoidance systems because it:

- Provides the secure wireless interface required by active safety applications;
- Supports high speed, low latency, short-range wireless communications;
- Works in high vehicle speed mobility conditions;
- Is designed to be tolerant to multi-path transmissions typical with roadway environments;
- Supports both inter-vehicle and vehicle to infrastructure (V2I) communications;
- Operates in a licensed (i.e.., interference protected) frequency band; and
- Is allocated for vehicle safety applications by a 1999 FCC Report & Order (75 MHz of spectrum) [2]

1.2.1 Description of System Operation

In V2V communications, vehicles equipped with a short range wireless transceiver and a GPS receiver regularly exchange safety-related information, including time, location, and further vehicle status data amongst neighboring vehicles. [3] The communication, in general, is provided as a single-hop, periodic broadcast (although multi-hop routing may also be used to extend the geographical range and region of message reception). [4] It is expected that periodic vehicle broadcast of safety information would be about 10 messages per second with an average message size between 250 and 350 bytes, including security. [5] The required transmission range of safety messages is about 300 meters for cooperative crash-avoidance safety applications. V2V technology would employ the wireless communication protocol based on IEEE 802.11p DSRC in the 5.9 GHz band. [6]

Figure 2 shows a simple nominal architecture of a V2V communication-based cooperative crash-avoidance system. The Sensor Data Handler (SDH) processes Host Vehicle (HV) GPS data such as vehicle location, heading, time, etc. and also the vehicle-bus data such as speed, acceleration, brake status, etc. The DSRC radio periodically (e.g., 10 times per second) transmits and receives safety broadcast data required for vehicle safety communication. Messages received from Remote Vehicles (RVs) by the DSRC radio are then processed by the Wireless Message Handler (WMH). Safety applications and algorithms within the Threat Processing & Threat Arbitration module evaluate the collision or other safety threat level of the HV with other communicating RVs in its vicinity. If a certain vehicle safety threat threshold is exceeded, as determined by the Threat Level being above a calibrated threshold, then the Threat Processing & Threat Arbitration module issues a threat notification via the Driver Notification module, and the driver of the HV is made aware of the safety threat via appropriate driver vehicle interfaces inside the vehicle (e.g.., haptic, visual, auditory warnings).

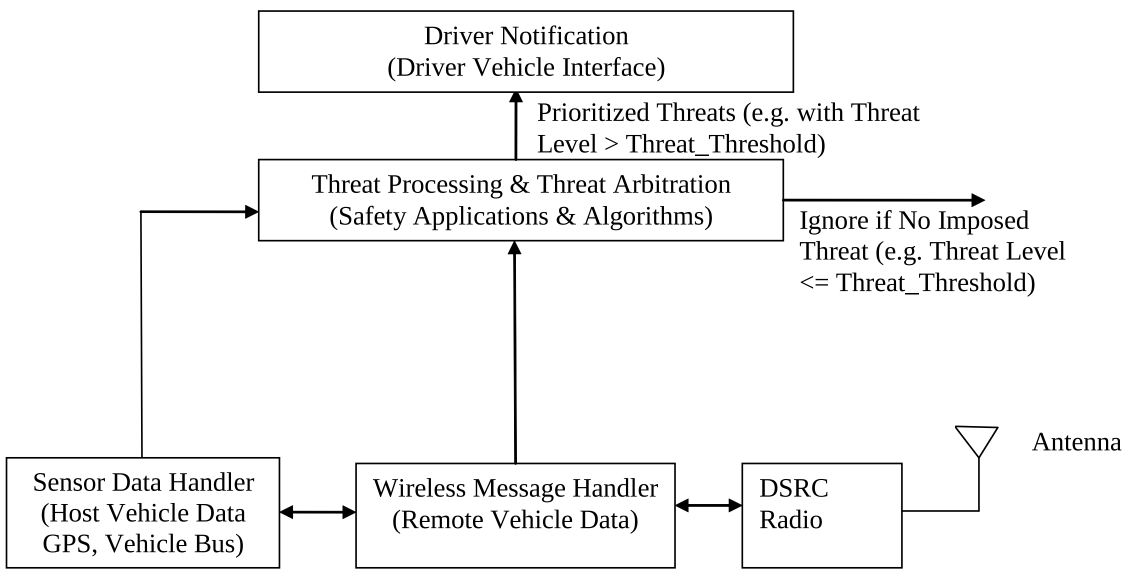


Figure 2 – Nominal Architecture of V2V Safety Communication System

Interoperability of V2V safety communication is ensured by following the Society of Automotive Engineers (SAE) J2735 Basic Safety Message (BSM). [7] As discussed above, BSMs are periodically broadcast (10 times per second). Event-driven BSMs are broadcast immediately upon event occurrence. The BSM consists of Parts I and II. Part I consists of vehicle state data that is so critical for vehicle safety applications that it must be included in every BSM. Part II consists of data that is required by applications at regular intervals (potentially at a reduced frequency), required to notify applications of a given event, or required for application processing. Figure 3 shows the components and format of the BSM in SAE J2735.

It is important to note that the information transmitted by the vehicles is completely anonymous. It does not include any personally identifying information such as an individual's name, license plate number, etc. The data is also transmitted with a sophisticated security system that ensures that only authorized vehicles are permitted to send and receive safety related information.

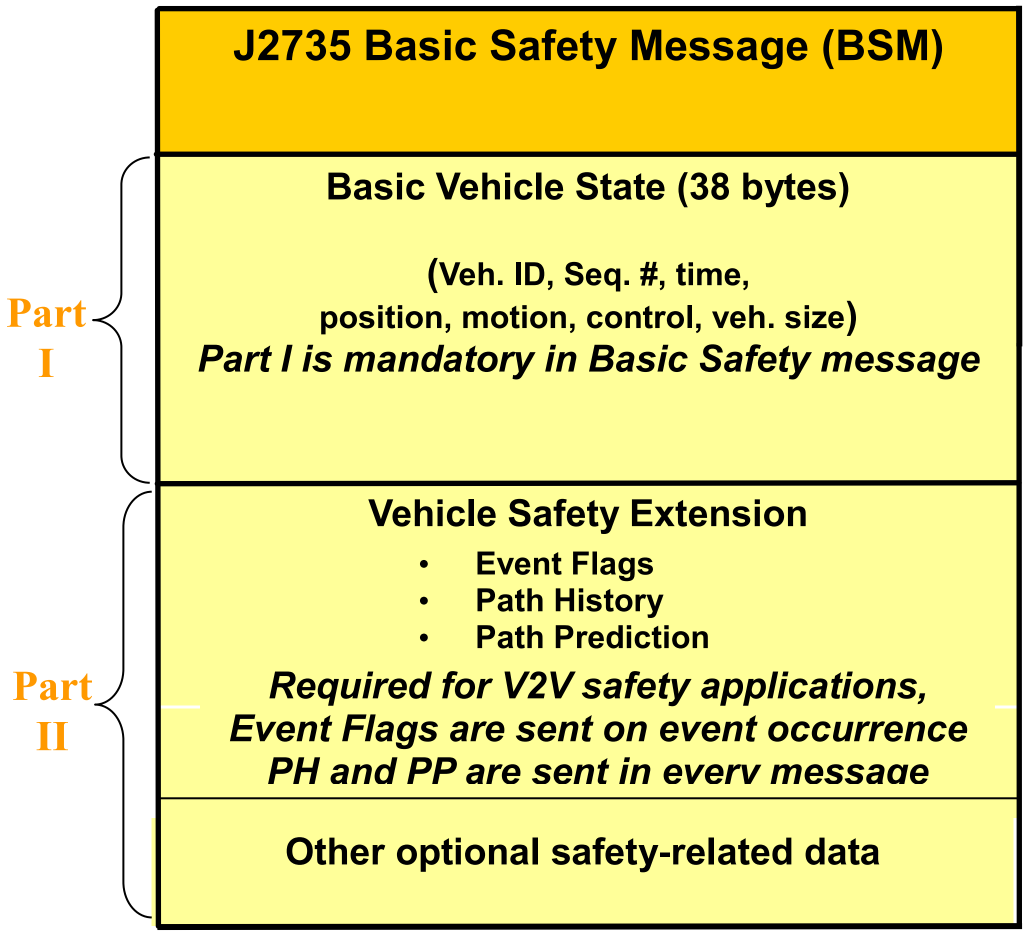


Figure 3 –V2V Safety Communication Message

1.2.2 Crash Scenarios and Safety Applications

During the Vehicle Safety Communications – Applications (VSC-A) Project, [6] the USDOT evaluated pre-crash scenarios based on the 2004 General Estimate Systems (GES) crash database. [8] This list served as the basis for the selection of the safety applications to be prototyped under the Project. Each crash scenario was assigned a composite crash ranking determined by taking the average of the crash rankings by frequency, cost, and functional years lost for each scenario. The crash scenarios were then sorted based on the composite ranking and analyzed to evaluate whether autonomous safety systems and/or vehicle safety communications would offer the best opportunity to adequately address the scenarios.

From this ranked list of crash scenarios (based on crash frequency, crash cost and functional years lost), the top eight (8) crash scenarios were selected. The selected crash-imminent scenarios were analyzed and potential, DSRC-based safety applications concepts capable of addressing them were developed. The crash-imminent scenarios and the applications selected are shown in Table 1. The VSC-A team, together with the USDOT, analyzed the scenarios in Table 1 and developed concepts for safety applications that could address them through vehicle safety communications. This analysis resulted in the identification of the following safety applications cooperative crash-avoidance safety system:

Emergency Electronic Brake Lights (EEBL)
The EEBL application enables a Host Vehicle (HV) to broadcast a self-generated emergency brake event to surrounding Remote Vehicles (RVs). Upon receiving the event information, the RV determines the relevance of the event and issues a warning to the driver, if appropriate. This application is particularly useful if the driver’s line of sight is obstructed by other vehicles or bad weather conditions (e.g., fog, heavy rain).

Forward Collision Warning (FCW)
The FCW application is intended to warn the driver of the HV of an impending rear-end collision with an RV ahead in traffic in the same lane and direction of travel. FCW is intended to help drivers avoid or mitigate rear-end vehicle collisions in the forward path of travel.

Blind Spot Warning+Lane Change Warning (BSW+LCW)
The BSW+LCW application is intended to warn the driver during a lane change attempt if the blind-spot zone into which the HV intends to switch is, or will soon be, occupied by another vehicle traveling in the same direction. Moreover, the application provides advisory information intended to inform the driver of the HV that a vehicle in an adjacent lane is positioned in a blind-spot zone of the HV when a lane change is not being attempted.

Do Not Pass Warning (DNPW)
The DNPW application is intended to warn the driver of the HV during a passing maneuver attempt when a slower moving vehicle, ahead and in the same lane, cannot be safely passed using a passing zone that is occupied by vehicles in the opposite direction of travel. In addition, the application provides advisory information intended to inform the driver of the HV that the passing zone is occupied when a vehicle is ahead and in the same lane and a passing maneuver is not being attempted.

Intersection Movement Assist (IMA)
The IMA application is intended to warn the driver of a HV when it is not safe to enter an intersection due to high collision probability with other RVs. Initially, IMA is intended to

help drivers avoid or mitigate vehicle collisions at stop sign-controlled and uncontrolled intersections.

Control Loss Warning (CLW)

The CLW application enables a HV to broadcast a self-generated control-loss event (e.g., loss of control on ice) notification to surrounding RVs. Upon receiving such event notification, the RV determines the relevance of the event and provides a warning to the driver, if appropriate.

Table 1 illustrates the mapping between the crash-imminent scenarios and the safety applications defined above.

Table 1: Mapping of Safety Applications to Crash-Imminent Scenarios

	V2V Safety Applications/ Crash Scenarios	**EEBL**	**FCW**	**BSW**	**LCW**	**DNPW**	**IMA**	**CLW**
1	**Lead Vehicle Stopped**		✓					
2	**Control Loss without Prior Vehicle Action**							✓
3	**Vehicle(s) Turning at Non-Signalized Junctions**						✓	
4	**Straight Crossing Paths at Non-Signalized Junctions**						✓	
5	**Lead Vehicle Decelerating**	✓	✓					
6	**Vehicle(s) Not Making a Maneuver – Opposite Direction**					✓		
7	**Vehicle(s) Changing Lanes – Same Direction**			✓	✓			
8	**LTAP/OD at Non-Signalized Junctions**						✓	

1.2.3 Example Concept of Operation for Safety Applications

Forward Collision Warning (FCW) and Avoidance Feature

Using V2V communications, the vehicle monitors messages from other vehicles up to 300 meters ahead. It then uses the information transmitted in safety messages from other vehicles, along with its own dynamic state information, to select lead vehicles of interest for this safety feature up to 150 meters away and in the same lane. Threat assessment calculations are performed periodically (e.g., every 100 ms) to determine, in real-time, whether there is a danger of rear-end collision with the vehicle ahead in the lane. The FCW & Avoidance feature in the HV warns the driver first (e.g., with visual icons and seat vibrations) and then automatically brakes (if the driver does not respond) if there is danger of a rear-end collision with the vehicle ahead. An illustration of a scenario for this feature is shown in Figure 4.

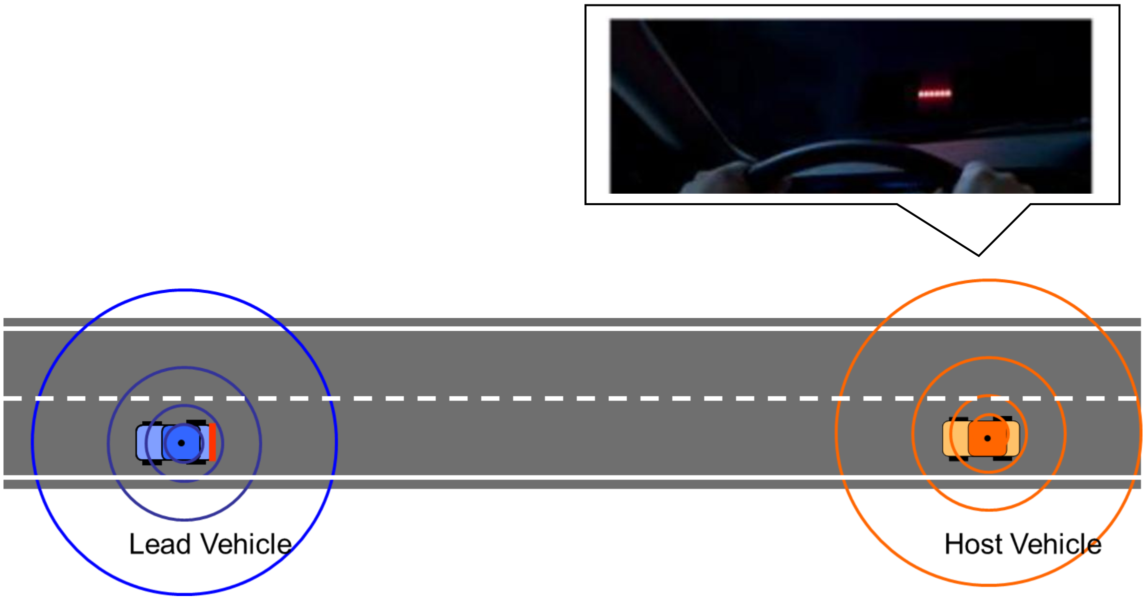


Figure 4 –Illustration of V2V Forward Collision Warning Feature

Intersection Movement Assist (IMA) Feature

Using V2V communications, the HV monitors messages from other vehicles at an intersection up to a quarter of a mile. It then uses the information transmitted in safety messages from other vehicles, along with its own dynamic state information, to select cross path RVs of interest for this safety feature. Threat assessment calculations are performed periodically (e.g.., every 100 ms) to determine, in real-time, whether there is a danger of intersection crash with a RV in its cross path of travel. Intersection Movement Assist feature in the HV warns the driver if there is danger of a straight crossing path crash with a RV at the intersection. An illustration of this feature is shown in Figure 5, where the HV is shown to have the right of travel and the RV is shown as potentially violating the stop bar at an intersection.

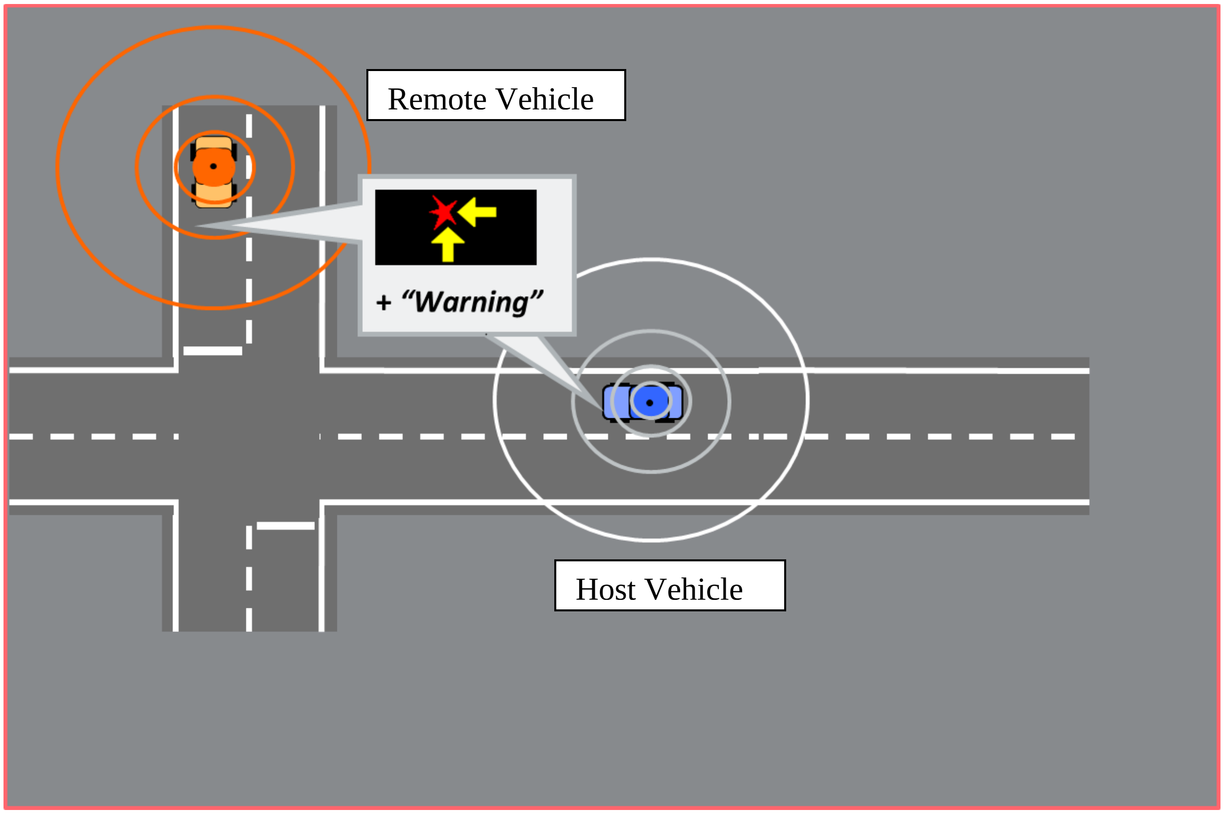


Figure 5 –Illustration of V2V Intersection Movement Assist Feature

1.3 SUSCEPTIBILITY OF DSRC-ENABLED SAFETY APPLICATIONS TO HARMFUL INTERFERENCE

For this section, we use as an example the cooperative Forward Collision Warning feature that provides alerts intended to assist drivers in avoiding or mitigating the rear-end collision. As described earlier, this safety feature of a V2V system may alert the driver to an approaching (or closing) conflict a few seconds before the driver would have detected such a conflict (e.g., if the driver's eyes were off-the-road), so the driver can take any necessary corrective action (e.g., steering, hard braking, etc.).

Key to driver acceptance of the FCW feature is appropriate crash alert timing, which refers to the necessary underlying vehicle-to-vehicle kinematic conditions for triggering crash alerts. The goal of the alert timing approach is to allow the driver enough time to avoid the crash, and yet avoid annoying the driver with alerts perceived as occurring too early, too often or unnecessarily.

The FCW equipped vehicle must be capable of detecting, classifying, tracking and monitoring "Remote Vehicles of Interest" (typically cars, trucks, motorcycles, etc.). When these estimated trajectories predict a collision course between the Following

Vehicle (FV) and Lead Vehicle (LV), a measure of crash threat (e.g.., Time-to-Collision or TTC) can be determined and then compared to the criterion used to trigger the FCW warning.

1.3.1 Time-to-Collision

Drivers constantly make judgments about how to adjust vehicle speed based on what is seen in the roadway ahead. Much of collision avoidance research investigates the ability of drivers to judge when braking is necessary to avoid an accident. Additionally, once a driver is braking, the driver must monitor and adjust the level of braking input to brake successfully. Time-to-collision is frequently used in literature [9] as a descriptor of how urgent a situation has become, as well as potentially how a driver perceives stimuli during an event.

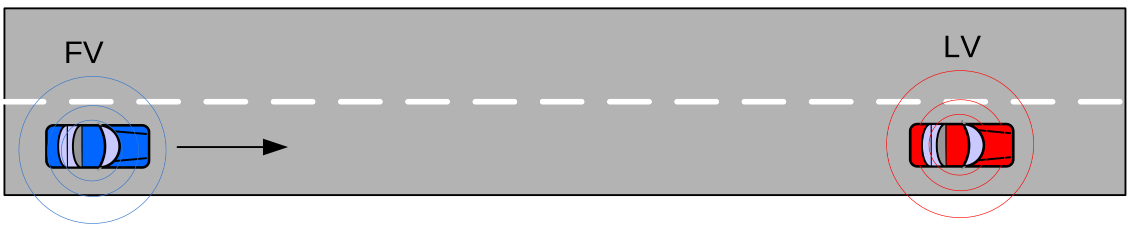


Figure 6 –Illustration of Following and Lead Vehicle in FCW

Consider the FCW scenario shown in Figure 6. Time-to-collision can be calculated or approximated using various measures and theories. In an event with a following and a lead vehicle, time-to-collision when approaching a stationary LV, or when the LV is moving at a constant rate (zero acceleration), is computed as,

$$TTC = \frac{-r}{v_r},\ TTC = \frac{-r}{v_r}, \qquad (1)$$

where r is the range between the vehicles and v_r v_r is the relative velocity, which is defined as

$$v_r = v_{LV} - v_{FV},\ v_r = v_{LV} - v_{FV}, \qquad (2)$$

where v_{LV} v_{LV} is the velocity of the LV and v_{FV} v_{FV} is the velocity of the FV.

Time-to-collision computed in this manner will be referred to as TTC. If the FV acceleration is assumed to be zero and the LV is accelerating (or decelerating), this LV acceleration is included in the equation as follows:

$$TTC = \frac{-v_r - \sqrt{v_r^2 - 2a_{LV}r}}{a_{LV}},$$

(3)

where a_{LV} $TTC = \dfrac{-v_r - \sqrt{v_r^2 - 2a_{LV}r}}{a_{LV}}$, a_{LV} is the acceleration of the LV (negative for a deceleration). Time-to-collision where acceleration of the LV (typically deceleration) is included will also be referred to as TTC.

1.3.2 Significance of Packet Error Rate (PER) and Inter-Packet Gap (IPG)

In general, the cooperative FCW feature requires that a vehicle has good real-time situational awareness and tracking of its neighboring vehicles, and then, based on such situational awareness, the system feature can provide advisory and warning information to the driver.

Two related performance metrics are important to the cooperative FCW system:

> PER: Ratio, expressed as a percentage, of the number of missed packets (i.e. safety messages) at a receiver from a particular transmitter and total number of packets sent by that transmitter; and
>
> IPG: Time, expressed in milliseconds, between successive successful packet (i.e. safety message) receptions from a particular transmitter.

Clearly, IPG is caused by PER, and a large IPG would result in poor performance of the cooperative FCW safety system by the vehicle not being able to perform good real-time situational awareness and tracking of its neighboring vehicles, as well as not being able to provide timely warnings of an imminent rear-end crash to the driver.

The USDOT's New Car Assessment Program (NCAP) FCW requirements are provided in Table 2. The FCW system must meet each of three crash alert test requirements. Each of the tests is to be conducted under clear, daytime weather conditions, and involves the FCW-equipped vehicle approaching a Lead Vehicle on a straight road at 45 MPH (72.4 kph). Furthermore, an alert must be issued prior to the time-to-collision (TTC) criterion associated with each test (shown in Table 2) in at least five of seven test trials, and must not fail to meet the criterion on two consecutive trials. [10]

Table 2. Overview of United States Department of Transportation New Car Assessment Program (NCAP) Forward Collision Warning (FCW) confirmation test requirements

NCAP FCW Test	Following Vehicle / Lead Vehicle Speeds	Time-to-Collision Requirement
Lead Vehicle Stopped (LVS)	45 MPH (72.4 kph) / 0 MPH (0 kph)	2.10 sec
Lead Vehicle Decelerating (LVD); (vehicles coupled at 30 m distance when lead brakes at 0.3 g's)	45 MPH (72.4 kph) / 45 MPH (72.4 kph)	2.40 sec
Lead Vehicle Moving (LVM) at a Lower Constant Speed	45 MPH (72.4 kph) / 20 MPH (32.2 kph)	2.00 sec

The LVD scenario, as shown in Figure 7, is presented for discussion.

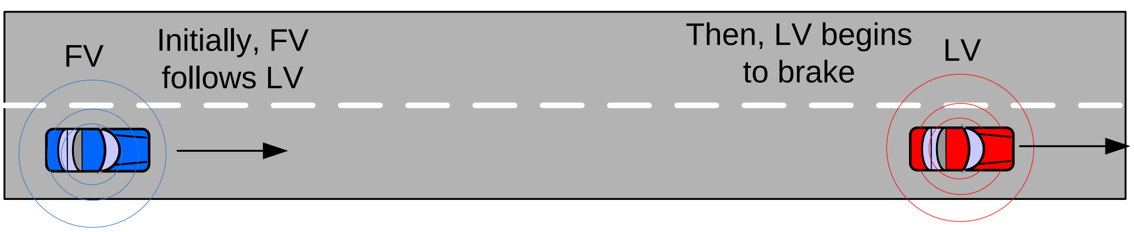


Figure 7 –Lead Vehicle Decelerating Scenario

Based on the LVD scenario described in Table 2, the cooperative FCW system must be capable of issuing an alert at a theoretical minimum TTC of 2.40 seconds. Based on Equation 3, the initial TTC when the lead vehicle initiates its braking of 0.3g is 4.5175 seconds. Assuming that the driver of the following vehicle is issued an FCW alert, following which he takes action to apply braking to his vehicle at a deceleration of 0.6 g after a driver reaction time of 1.5 seconds, the following statements can be made:

- If the IPG is significant such that the warning is provided by the system with a delay greater than 3.0175 seconds after the lead vehicle initiates braking, the driver will have less than 1.5 seconds to react to the warning. Based on the assumed driver reaction time of 1.5 seconds, the following vehicle will crash into the lead vehicle with a significant Delta Speed of 13.3 m/s.

- If the IPG is such that the warning is provided by the system with a delay of 2.5175 seconds after the lead vehicle initiates braking, the driver will have the time to react to the warning. In this situation the warning is provided at a TTC of 2.0 seconds. However, based on the assumed driver reaction time of 1.5 seconds, the following vehicle will still crash into the lead vehicle with a Delta Speed of 10.1 m/s.

- If the IPG is such that the warning is provided by the system with a delay of 2.1175 seconds after the lead vehicle initiates braking, the driver will have sufficient time to react to the warning. In this situation, the warning is provided at a TTC of 2.4 seconds. However, based on the assumed driver reaction time of 1.5 seconds, the following vehicle will still crash into the lead vehicle with a Delta Speed of 7.0 m/s.

- If the IPG is such that the warning is provided by the system with a delay of 1.675 seconds after the lead vehicle initiates braking, the driver will have sufficient time to react to the warning. In this situation the warning is provided at a TTC of 2.8425 seconds. Based on the assumed driver reaction time of 1.5 seconds, the following vehicle will be prevented from crashing into the lead vehicle.

Thus, for the stated driver to prevent a crash in this scenario, the warning should be provided at a TTC larger than 2.84 seconds. However, prior to issuing this alert, the system must detect, classify, and estimate the range and range-rate to the lead vehicle and accommodate various system latencies (i.e., network communication, interface delays, etc.). Consequently, in order to ensure robust operation, the cooperative FCW system must be able to detect, classify and estimate the range (TTC) to the target lead vehicle at a TTC of at least 3.5 seconds. Therefore, in this example, the IPG should be less than 1.0 seconds for initial detection, and subsequently to track the target vehicle, classify and estimate the threat continuously, the IPG from the lead vehicle should be typically low, nominally 100 ms until the warning is provided.

UNII devices operating in the DSRC Band can cause significant interference to packet (i.e. safety messages) reception in cooperative safety systems, leading to unknown and perhaps very high IPG and PER. Consequently, they could negatively affect the performance of cooperative safety applications and the benefits to be derived from these safety systems. IPG and PER would also affect security verification in cooperative safety systems since the messages with certificates attached may be lost or delayed due to interference from UNII devices in the DSRC Band. Significant real world testing is required to assess the consequence of interference from UNII devices.

1.4 CO-CHANNEL INTERFERENCE MECHANISMS

This section describes a number of the mechanisms that could be involved in co-channel interference if DSRC and Wi-Fi technologies share the same spectrum. Further technical details regarding these mechanisms are contained in a later section entitled – “Co-channel Interference Analysis”.

1.4.1 Lower Layer Sensing Mechanisms

Although both DSRC and Wi-Fi technologies share the lower layer technologies of IEEE 802.11, there are differences in the options selected from the IEEE 802.11 standard. One of the most significant potential causes of co-channel interference is the different channel width of 10 MHz used by DSRC, as compared to the 20 MHz minimum channel width used for Wi-Fi. The 10 MHz channel width is allowed under IEEE 802.11, and was selected for DSRC for specific characteristics of vehicles traveling at highway speeds. The 10 MHz channels have been thoroughly field-tested to support V2V cooperative safety applications among vehicles traveling at highway speeds.

As a result of the different channel widths used by DSRC and Wi-Fi technologies, the Carrier Sense Multiple Access (CSMA) mechanism in IEEE 802.11 may not be interoperable between these two technologies. The DSRC devices have been designed to detect the IEEE 802.11 preamble within the 10 MHz channel width, so these devices may not be able to detect the Wi-Fi packet preamble sent on a 20 MHz channel. The current Wi-Fi devices have not been designed to detect channels that are 10 MHz wide, so they may need to be modified to detect the 10 MHz DSRC channels in order to detect DSRC packets and avoid interfering with DSRC transmissions. Wi-Fi devices would also need to be modified to be capable of verifying that two or more DSRC channels are clear simultaneously.

1.4.2 Application Layer Sensing Mechanisms

DSRC crash-avoidance safety applications are expected to experience channel congestion in vehicle traffic situations that are likely to occur under realistic roadway conditions, especially during peak traffic periods in major metropolitan centers. Application layer protocols that adjust transmission power and/or BSM transmission interval timing based upon the likelihood of vehicles being in a conflict situation have been developed to address the expected channel congestion resulting from these dense traffic situations. It is expected that all DSRC devices supporting V2V cooperative crash-avoidance safety applications will participate in this application layer channel congestion mitigation protocol in order to ensure that the appropriate vehicles are able to communicate effectively. Non-DSRC devices will need to sense the V2V safety use of the DSRC channel and move to another channel, or else utilize the application layer channel congestion mitigation protocol in order to share the channel without causing harmful interference to the V2V safety applications.

1.4.3 Power Disparity Challenge

The current implementations of V2V safety applications utilize DSRC transmission power in the range of 18-20 dBm EIRP. This corresponds roughly to a maximum of 100 mW in transmitter output. This power level has been shown through significant field testing to provide suitable range to support the V2V crash-avoidance safety applications without creating excessive channel congestion outside the range necessary to support these safety applications.

If non-DSRC devices are to share the spectrum with DSRC devices and are operated with much higher power, such as "…the lesser of 1 Watt and 17dBm+10 Log (B) where B is 26 dB emission bandwidth," then the large power differential will contribute to extensive harmful interference for the DSRC V2V safety applications.

With critical V2V safety applications operating at much lower power levels in the proposed shared DSRC spectrum, the prospect of asymmetrical sensing issues represents a major concern. The transmission range of the U-NII devices will be much farther than the V2V DSRC safety devices, due to the power differential. The U-NII devices are likely to initiate transmissions to the DSRC devices, due to their limited ability to sense the lower-powered DSRC devices within the range of the U-NII units. When the U-NII devices cannot detect the lower-powered DSRC devices, U-NII packets will be sent at the same time as the DSRC units are sending packets for critical safety applications, causing the DSRC packets to be unreadable by DSRC receiving devices. In this situation, it is likely that significant sequences of DSRC packets supporting crash-avoidance safety applications could be unreadable.

1.4.4 Aggregate U-NII Noise Floor Mechanisms

In major metropolitan areas, channel congestion on DSRC V2V safety channels is expected to be encountered in fairly commonly-occurring traffic situations. These major metropolitan areas are also where significant numbers of deployed U-NII devices likely will be operated. Even if the U-NII devices were running at very low power levels, or operating at significant distance from vehicles using DSRC to support V2V safety applications, the aggregation of many such U-NII devices in operation would likely raise the noise floor within the DSRC channel, causing potentially harmful interference with DSRC V2V cooperative crash-avoidance safety applications.

1.5 CO-CHANNEL INTERFERENCE ANALYSIS

U-NII-4 devices sharing the DSRC band could provide harmful interference to incumbent DSRC operations unless more constraints on the operation of the U-NII-4 devices are required. The following proposed U-NII-4 characteristics and related FCC NPRM paragraph numbers are helpful when considering such spectrum sharing:

a) A max conducted power for point-to-point (PtP) and non-PtP of 30 dBm [¶30, ¶97]

b) A max antenna gain of 23 dBi (PtP) and 6 dBi (non-PtP) [¶33]

c) A max EIRP of 53 dBmi (PtP) and 36 dBmi (non-PtP), based on a and b above

d) 802.11a/n/ac OFDM channel bandwidths of 20, 40, 80, and 160 MHz [¶18]

With a goal of maintaining DSRC operations and protocols already developed by carmakers and used in current USDOT field trials, we discuss the following concerns:

- Interference issues due to high U-NII-4 EIRP;
- DSRC detection issues by U-NII-4 devices;
- Physical carrier sensing of U-NII-4 emissions by DSRC devices;
- Diverging approaches on packet size;
- Implications on DSRC congestion control schemes; and
- Noise floor increase from RLAN transmissions.

1.5.1 Interference Issues Due to High U-NII-4 EIRP

The typical EIRP used in DSRC equipped vehicles and in USDOT field trials is 20 dBmi. However, the proposed max EIRP for U-NII-4 transmitters is much higher: 53 dBmi (PtP) and 36 dBmi (non-PtP). This creates an asymmetric EIRP in the cross-detection process, and some DSRC transmitters will be interfered with before their presence can be detected. Without hearing these DSRC transmissions, U-NII-4 transmitters are likely to emit packets over the top of the DSRC BSMs.

1.5.2 DSRC Detection Issues by U-NII-4 Devices

DSRC uses a half-rate function (10 MHz channels) available in 802.11a devices that implement the 802.11j extension. On any given 10 MHz DSRC channel, it is possible that 802.11a/n/ac devices with such an 802.11j extension could detect DSRC packets as valid OFDM frames and thus avoid further operation on that channel. One issue is that 20, 40, or 80 MHz U-NII-4 transmitters will need to verify a clear channel on 2 or more DSRC channels simultaneously before transmitting. Since this multiple channel sensing operation is likely to be difficult, effective sensing technology must be developed and tested.

If the U-NII-4 devices cannot detect a DSRC signal as a valid OFDM waveform (because they do not use 802.11j or they are not OFDM devices), they may be able to detect DSRC packets as noise energy using physical carrier sensing. However, this physical carrier detection level is relatively high (about -65dBm). Initial DSRC communications at max 300m range occur with a received signal strength (RSS) as low as -92 to -94dBm. U-NII-4 devices simply will not be able to detect and avoid interference at such low RSS values. The issue of nomadic departures and arrivals will still apply, even if physical carrier sensing can operate at such low RSS levels.

1.5.3 Physical Carrier Sense of U-NII-4 Emissions by DSRC Devices

Current DSRC devices cannot easily detect 20, 40, 80, or 160 MHz transmissions in the DSRC band. Although not required under the Commission’s rules, the manufacturers of DSRC devices might feel compelled to attempt a redesign of such devices in order to use physical carrier sensing to sense U-NII-4 transmissions in the DSRC spectrum. Assuming high packet traffic and channel usage from U-NII-4 devices, if DSRC transmitters did back off upon sensing U-NII-4 packets, the DSRC devices would likely be suspended for significant periods of time that could result in BSM latency and higher DSRC packet errors. This would certainly reduce the efficacy of the DSRC systems.

1.5.4 Diverging Approaches on Packet Size

DSRC BSMs sent are small broadcasted packets of 250 to 350 bytes (0.5ms range for transmit duration), which allows very short transmissions using the WAVE Short-Message (WSM) protocol, at a robust 6 mbps burst data rate, and conveyed among highly-mobile, ad hoc nodes. Although each transceiver sends only 10 BSMs per second, the packet success rate must be high in order to track the movement of nearby vehicles and determine with confidence a warning status for the driver.

U-NII-4 devices such as IEEE 802.11ac mandate the use of longer aggregated packets up to 5.5ms in length. A single U-NII-4 packet could collide with a number of BSMs, even assuming the U-NII-4 device had detected no packets at the time immediately preceding its own transmission. Therefore, it would likely be necessary to limit the U-NII-4 devices to a specific short packet length interval and a very low duty cycle in order to avoid harmful interference to the DSRC communications.

1.5.5 Implications on DSRC Congestion Control Schemes

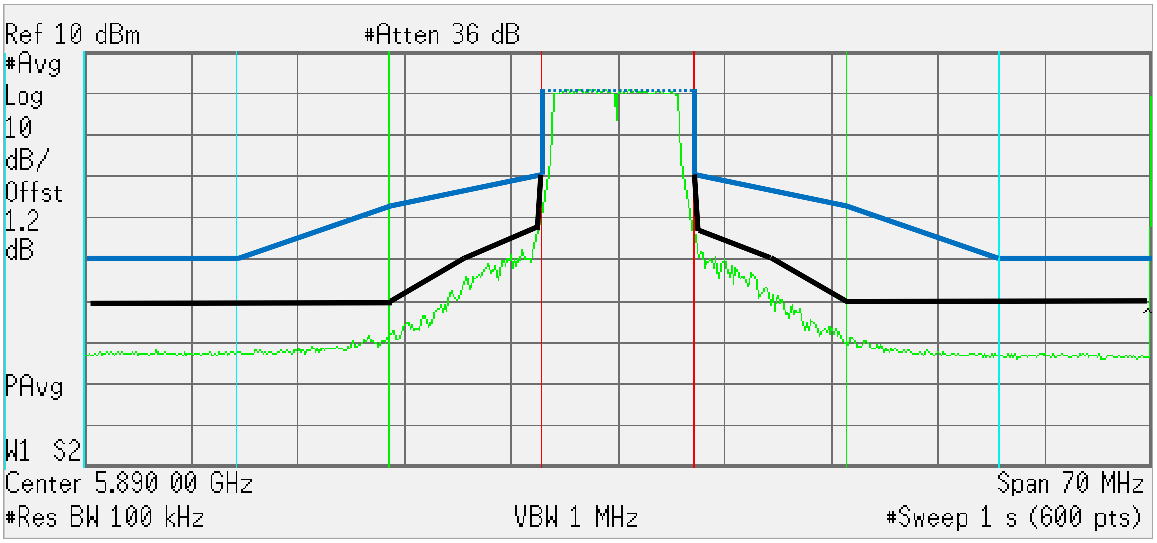
DSRC defines and detects a range of acceptable packet congestion levels and implements application-level protocols when needed to lower and maintain a level of performance. It is not known if it would be feasible for U-NII-4 devices to be aware of the DSRC application layer channel congestion mitigation factors or protocols. Further, it is likely that U-NII-4 nodes will also be concentrated in major urban areas where V2V channel congestion is most likely. This conjunction of situations illustrates the need to create interference mitigation approaches such that U-NII-4 devices can effectively sense and vacate the congested DSRC channels being used for safety applications, especially in major metropolitan areas.

1.5.6 Noise Floor Increase from U-NII-4 Transmissions

DSRC safety communications includes V2V links to the 300m range, when RSS is low, safety links begin tracking, and PER must be low. Because proposed U-NII-4 transmissions in the DSRC band overlap the DSRC channels and have undetectable preambles, they would be detected by DSRC receivers as high noise signals. As the highly mobile nomadic vehicles pass through a U-NII-4 hotspot or the large coverage area of a U-NII-4 Wireless Internet Service Provider (WISP), the noise floor in the DSRC mobile receivers will be raised. This makes receiving BSMs difficult, particularly at the 200 to 300 meter range, where vehicles must first be tracked. It is not clear what technical mitigation strategies are available to counter this effect and allow sharing of the channel with U-NII-4 devices while maintaining reliable V2V links to support V2V and related low-latency safety applications.

U-NII-4 transmitters inside the DSRC band add significantly more noise to adjacent DSRC channels than DSRC transmitters themselves. This is shown in the spectral plot below.

The U-NII-4 TX mask (example 20 MHz transmitter) is shown in blue. The DSRC mask is shown in black. A DSRC mask-compliant 20 dBm signal is shown in green. The U-NII-4 out-of-band mask segments are overlaid on the 10 MHz signal, although they apply to a 20 MHz waveform. The comparison is valid although U-NII-4 operates in wider bandwidths because they can also operate at 10 dB to 20 dB more EIRP than typical in-vehicle DSRC transmitters. As one can observe, the U-NII-4 mask allows much more noise in adjacent bands. This may be acceptable for hot spots with clustered clients separated by frequency from other hotspots, but OBUs on adjacent frequencies are only separated by a lane width. In-band U-NII-4 transmitters will likely generate excessive noise that will de-sense and degrade the safety links.



1.6 INTERFERENCE DUE TO STRONG OUT-OF-BAND SIGNALS

This section describes a number of the mechanisms that could be expected to be involved with interference originating outside the particular DSRC channel. Further technical details regarding these mechanisms are contained in the section following this one, titled: "Out-of-band Interference Analysis".

1.6.1 Adjacent DSRC Channel Interference Mechanisms

The DSRC channel to be used for V2V cooperative crash-avoidance safety (Channel 172) was chosen to be purposely separated from higher-powered DSRC control and intersection channels in order to minimize adjacent channel and next-adjacent channel interference. This spectral separation of DSRC channels was implemented even though there are low-density expectations for RSEs compared to U-NII access points - especially in major metropolitan areas.

If U-NII devices are sharing the DSRC spectrum and operating at higher power levels, such as "…the lesser of 1 Watt and 17 dBm+10 Log (B) where B is 26 dB emission bandwidth," they would be expected to cause harmful interference to V2V safety applications when operating on channels adjacent to the DSRC channel used for V2V safety.

1.6.2 Adjacent U-NII Band Interference Mechanisms

Even if U-NII devices were confined to spectrum that was not within the DSRC range, the U-NII devices could cause harmful interference to the V2V safety applications if the U-NII bands were immediately, or closely adjacent to, the DSRC channel being used for V2V safety. This is especially true with the maximum power levels for U-NII devices mentioned above. In addition to the higher power levels, higher gain antennas are also expected to be used by the U-NII devices. These higher gain antennas are expected to increase the likelihood of harmful interference to the DSRC safety applications from U-NII devices operating in adjacent bands.

1.7 OUT-OF-BAND INTERFERENCE ANALYSIS

DSRC transmissions are subject to interference due to unwanted emissions from U-NII-3 devices. They are also subject to interference from emissions outside the occupied channel of a U-NII-4 device. U-NII-4 devices can also provide co-channel interference to DSRC transmissions, as addressed in an earlier section.

Unwanted emission limits proposed by the Commission for the U-NII-3 band are: "below -17 dBm/MHz within 10 megahertz of the band edge, and below -27 dBm/MHz beyond 10 megahertz of the band edge." [¶34] The Commission invites "comment on whether any of these techniques [including limiting unwanted emissions] would be beneficial in protecting other incumbents from interference, not only in the U-NII-2C band but also in other segments of the 5 GHz band." [¶53].

While the Commission proposes OOBE limits for an unlicensed device operating in the U-NII-4 band, it does not define out-of-channel limits for such a device *within* the U-NII-4 band. For example, consider a U-NII-4 device that occupies 20 MHz Ch. 177 (5.875-5.895 GHz), which corresponds to 10 MHz DSRC channels 176 and 178. There are no defined limits on the emissions of such a device in non-overlapping 10 MHz DSRC channels 172, 174, 180, 182, or 184. It is clear that without such limits the U-NII-4 device can interfere with the reception of a DSRC transmission in those non-overlapping channels. The draft IEEE P802.11ac D5.0 standard includes transmit spectral mask limits, which impose relative out-of-channel emission constraints. An example transmit spectral mask for 20 MHz occupied bandwidth is shown in Figure 9 below. Given a transmit power in the occupied channel, it is possible to compute worst case out-of-channel emissions using this mask, and the impact of such emissions on DSRC packet reception.

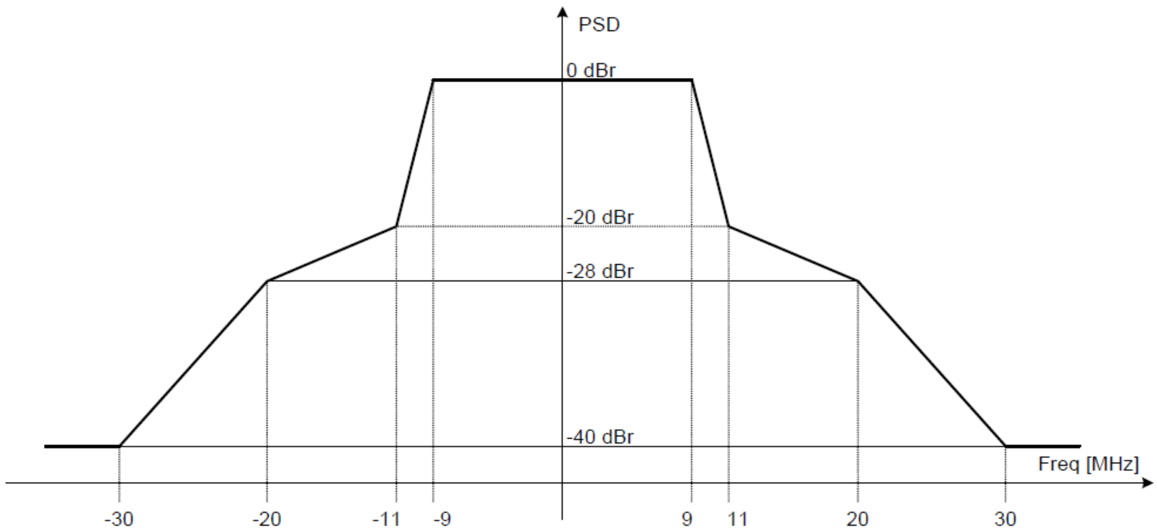


Figure 8 –Example 20 MHz Transmit Spectrum Mask (copied from IEEE P802.11ac D5.0)

We consider the following cases:

- Impact of unwanted emissions from a U-NII-3 device on a DSRC transmission in 10 MHz DSRC channel 172;
- Impact of unwanted emissions from a U-NII-3 device on a DSRC transmission in a 10 MHz DSRC channel above channel 172, e.g.., channel 174;
- Impact of unwanted emissions from a 20 MHz U-NII-4 device on a DSRC transmission in an adjacent 10 MHz channel, e.g.., from a U-NII-4 transmission in 20 MHz channel 177 on a DSRC transmission in 10 MHz DSRC channel 174 or 180;
- Impact of unwanted emissions from a 20 MHz U-NII-4 device on a DSRC transmission in a second-from-adjacent 10 MHz channel, e.g.., from a U-NII-4 transmission in 20 MHz channel 177 on a DSRC transmission in 10 MHz DSRC channel 172 or 182; and
- Impact of unwanted emissions from a 20 MHz U-NII-4 device on a DSRC transmission in a third-from-adjacent 10 MHz channel, e.g.., from a U-NII-4 transmission in 20 MHz channel 177 on a DSRC transmission in 10 MHz DSRC channel 184.

1.7.1 Impact of Unwanted Emissions from a U-NII-3 Device on a DSRC Transmission in 10 MHz DSRC Channel 172

DSRC 10 MHz Ch. 172 occupies the 5.855-5.865 GHz band. The U-NII-3 band edge is 5.850 GHz. According to the proposed unwanted emission rule for U-NII-3 [¶34] there can be as much as -17 dBm/MHz in the 5.855-5.860 GHz band, for a total of 100 microwatts. Furthermore, there can be as much as -27 dBm/MHz in the 5.860-5.865 GHz

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band, for a total of 10 microwatts. Therefore, there can be 110 microwatts of unwanted emission (-9.6 dBm) in Ch. 172 from a U-NII-3 device.

DSRC transmissions use 20 dBm EIRP transmit power by default. They also use QPSK with ½ rate coding [Ref. IEEE 802.11-2012] by default, the successful decoding of which requires approximately 7 dB of Signal-to-interference-and-noise (SINR) ratio. Given the DSRC transmit power, U-NII-3 unwanted emission power, and 7 dB SINR requirement, there is a 20 + 9.6 – 7 = 22.6 dB power margin for the DSRC signal at the transmission point. However, both the DSRC signal and the U-NII-3 interference power experience attenuation in reaching the DSRC receiver. The DSRC signal can be correctly decoded if the DSRC signal attenuation is no more than 22.6 dB higher than the U-NII-3 interference attenuation. Given a path loss model, the 22.6 dB power margin can also be thought of as a relative distance margin. If, for simplicity, one assumes a path loss exponent of 2, the 22.6 dB power margin represents an increase in distance of about 13.5 times, i.e. the DSRC devices can be no more than 13.5 times farther apart than the U-NII-3 device is from the DSRC receiver. Many collision avoidance scenarios require safety message communication ranges on the order of 300 meters between DSRC devices. If the DSRC transmitter is 300 meters from the DSRC receiver, a U-NII-3 device with worst case unwanted emissions whose transmission overlaps in time with the DSRC transmission will likely cause harmful interference if it is within 300/13.5 = 22.2 meters of the DSRC receiver.

Figure 9 illustrates a scenario in which a DSRC transmission from a leading car in DSRC Channel 172 overlaps in time with a U-NII transmission from a device in a nearby building. The U-NII-device is within a radius X of a trailing car that is 300 meters from the leading car. According to this analysis, if the U-NII device is within 22.5 meters of the trailing car, its unwanted emission in Channel 172 can prevent successful decoding of the DSRC transmission.

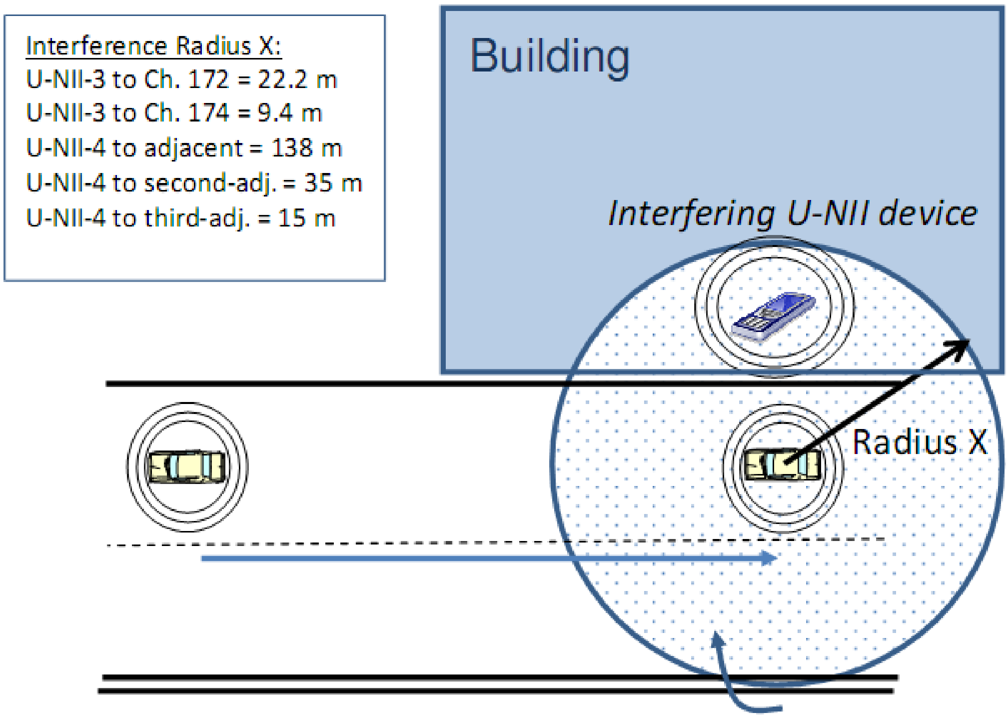

Figure 9 –Out-of-Band Interference Scenario

1.7.2 Impact of Unwanted Emissions from a U-NII-3 Device on a DSRC Transmission in 10 MHz DSRC Ch. 174

DSRC 10 MHz Ch. 174 occupies the 5.865-5.875 GHz band. In this channel, and higher numbered channels, unwanted emissions from a U-NII-3 device can have a power density as high as -27 dBm/MHz, or 20 microwatts (-17 dBm) for the 10 MHz channel. Using the same assumptions as above there is a 30 dB power margin, i.e. the DSRC transmission can tolerate as much as 30 dB additional attenuation in reaching the DSRC receiver compared to that experienced by the worst case unwanted emission energy from the U-NII-3 device in reaching the DSRC receiver. If the DSRC transmitter is 300 meters from the DSRC receiver, the U-NII-3 device transmitting an overlapping packet will likely cause harmful interference if it is within 300/32 = 9.4 meters of the DSRC receiver.

1.7.3 Impact of Unwanted Emissions from a U-NII-4 Device in 20 MHz Ch. 177 on a DSRC transmission in adjacent 10 MHz DSRC Ch. 174 or 180

DSRC 10 MHz Ch. 174 occupies the 5.865-5.875 GHz band, and Ch.180 occupies the 5.895-5.905 GHz band. These channels are adjacent to 20 MHz Ch. 177, which occupies the 5.875-5.895 GHz band. See Figure 10 below:

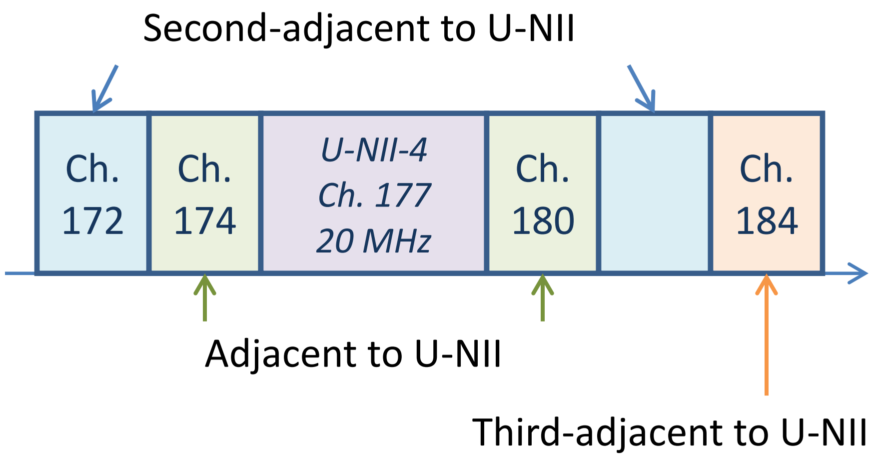

Figure 10 –Example: Interference from U-NII 20 MHz Ch. 177

According to the Commission's proposed rules, a U-NII-4 device transmitting in 20 MHz Ch. 177 can emit as much as 17 dBm/MHz in its occupied channel. [¶97] As noted above, there are no limits on unwanted out-of-channel emissions in the Commission's rules. However, using the transmit spectrum mask in Figure 8, one can compute worst case unwanted out-of-channel emissions for a device that conforms to the draft standard. In this case, the emissions are relative to the in-channel power spectral density of 17 dBm/MHz. Integrating over the frequency offset range 10 to 20 MHz, the power of unwanted emissions in an adjacent 10 MHz channel can be as high as 6.3 dBm (we approximate the integral with a sum using power spectral density granularity 100 kHz).

Using the same assumptions as above, i.e. 20 dBm DSRC transmission and 7 dB SINR required, the power margin between the DSRC signal and the U-NII-4 unwanted emission is only 6.7 dB. This translates to a distance factor of 2.2. If the DSRC transmitter is 300 meters from the DSRC receiver, the U-NII-4 device transmitting an overlapping packet will likely cause harmful interference if it is within 300/2.2 = 138 meters of the DSRC receiver in Ch. 174 or Ch. 180.

1.7.4 Impact of Unwanted Emissions from a U-NII-4 Device in 20 MHz Ch. 177 on a DSRC transmission in second-adjacent 10 MHz DSRC Ch. 172 or 182

Using a similar analysis to the prior section, the power of the unwanted emissions in 10 MHz channels second-from-adjacent to a 20 MHz U-NII-4 transmission can be obtained by integrating over the frequency offset range 20 to 30 MHz in Figure 8. If the U-NII-4 20 MHz transmission uses a maximum power density of 17 dBm/MHz, this unwanted emission power can be as high as -5.6 dBm.

The power margin between a second-adjacent-channel DSRC signal and U-NII-4 interference is therefore 18.6 dB. This translates to a distance factor of 8.5. If the DSRC transmitter is 300 meters from the DSRC receiver, the U-NII-4 device transmitting an overlapping packet will likely cause harmful interference if it is within 300/8.5 = 35 meters of the DSRC receiver in Ch. 172 or Ch. 182.

1.7.5 Impact of Unwanted Emissions from a U-NII-4 Device in 20 MHz Ch. 177 on a DSRC transmission in third-adjacent 10 MHz DSRC Ch. 184

Using a similar analysis to that used in the prior section, the power of the unwanted emissions in 10 MHz channels third-from-adjacent to a 20 MHz U-NII-4 transmission can be obtained by integrating over the frequency offset range 30 to 40 MHz in Figure 8. The mask is flat here at -40 dBm, so if the U-NII-4 20 MHz transmission uses maximum power density 17 dBm/MHz, this unwanted emission power in 10 MHz can be as high as -13 dBm.

The power margin between a third-adjacent-channel DSRC signal and U-NII-4 interference is therefore 26 dB. This translates to a distance factor of 20. If the DSRC transmitter is 300 meters from the DSRC receiver, the U-NII-4 device transmitting an overlapping packet will likely cause harmful interference if it is within 300/20 = 15 meters of the DSRC receiver in Ch. 184.

While Sections 1.7.3-1.7.5 assume the U-NII device uses maximum power, the interference resulting from even moderate power (7 dBm/MHz) U-NII-4 transmissions could still be significant. A 10 dB reduction in U-NII transmit power increases the power margin by 10 dB. In the case of a DSRC transmitter that is 300 meters from the DSRC receiver, the 10 dB change in margin means the interferer could be approximately 4.4 times closer before it caused DSRC packet decoding failure. For example, the adjacent channel interference range (Section 1.7.3) would be reduced from 138 meters to 31 meters.

1.8 CONCLUSIONS

V2V communications technology is a crucial component of the cooperative crash-avoidance system. 5.9 GHz DSRC is the only technology that has been proven to support the range and latency requirements of the cooperative crash-avoidance system. Besides the initial focus on the deployment of 5.9 GHz DSRC for cooperative crash-avoidance, other uses of the DSRC spectrum are under development, or anticipated. These include public safety applications, pre-crash damage mitigation applications, automated driving systems, support for V2V safety security system communications, as well as mobility and environmental applications.

Based on deployment planning work underway in the United States, and complementary work in Europe and Japan, it is envisioned that this DSRC-based V2V crash-imminent safety system will be extended to include other applications that will require additional messages and additional channels for communication. These applications will offer additional safety, mobility and environmental benefits. These additional applications include both safety and automation applications that also require low-latency communication, as well as other mobility and environmental applications that are more latency tolerant.

Although both DSRC and Wi-Fi technologies share the lower layer technologies of IEEE 802.11, there are significant differences in the options selected from the IEEE 802.11 standard. As a result of the different channel widths used by DSRC and Wi-Fi technologies, the Carrier Sense Multiple Access (CSMA) mechanism in IEEE 802.11 may not be interoperable between these two technologies. Current Wi-Fi receivers would need to be designed to detect possibly multiple 10 MHz DSRC channels in order to detect DSRC packets and avoid interfering with DSRC transmissions.

Application layer protocols that adjust transmission power and/or BSM transmission interval timing based upon the likelihood of vehicles being in a conflict situation have been developed to address the expected channel congestion resulting from these dense traffic situations. Non-DSRC devices sharing the DSRC spectrum would need to participate in this application layer channel congestion mitigation protocol in order to ensure that the appropriate vehicles are able to communicate effectively, or else employ interference mitigation approaches that allow U-NII-4 devices to vacate the congested DSRC channels being used for safety applications, especially in major metropolitan areas.

Because U-NII-4 transmissions in the DSRC band overlap the DSRC channels and could have undetectable preambles, they are detected by DSRC receivers as high noise signals. It is not clear what technical mitigation strategies might be used to counter this effect and allow sharing of the channel with U-NII-4 devices while maintaining reliable V2V links to support V2V and related low-latency safety applications. This situation also suggests that U-NII-4 devices would likely need some approach to vacate congested DSRC safety channels in major metropolitan areas.

U-NII devices have the potential to cause harmful interference to DSRC transmissions due to unwanted out-of-band emissions. This harmful interference could come from a U-NII device located in the same vehicle as the DSRC receiver, or in an adjacent vehicle. Furthermore, in the scenarios without an intervening channel between the U-NII device and the DSRC transmission, the harmful interference could come from a U-NII device located in a building nearby the vehicle with the DSRC receiver.

The potential for harmful interference from U-NII devices could span multiple DSRC transmissions. For example, a 4-millisecond U-NII transmission could interfere with the reception of seven DSRC transmissions spaced at 600 microsecond intervals. The harmful interference scenarios discussed above could be persistent throughout the time period that the U-NII device and the DSRC receiver are within range of each other. Some type of function that recognizes one instance of interference and avoids subsequent instances would need to be developed.

Additional interference mitigation technologies may also be needed in order to satisfy the requirement that U-NII devices do not cause harmful interference to incumbent DSRC operations. This additional mitigation could be achieved in a variety of ways, for example through a specific DSRC detector in the U-NII device, such that upon detection of a DSRC transmitter the U-NII device ceases to use its current band. Another example would be more stringent unwanted emission limits for U-NII-3 and U-NII-4 devices.

For all the reasons mentioned above, extensive field- and bench-testing is required for any U-NII algorithm proposed for channel sharing with DSRC devices.

1.9 REFERENCES

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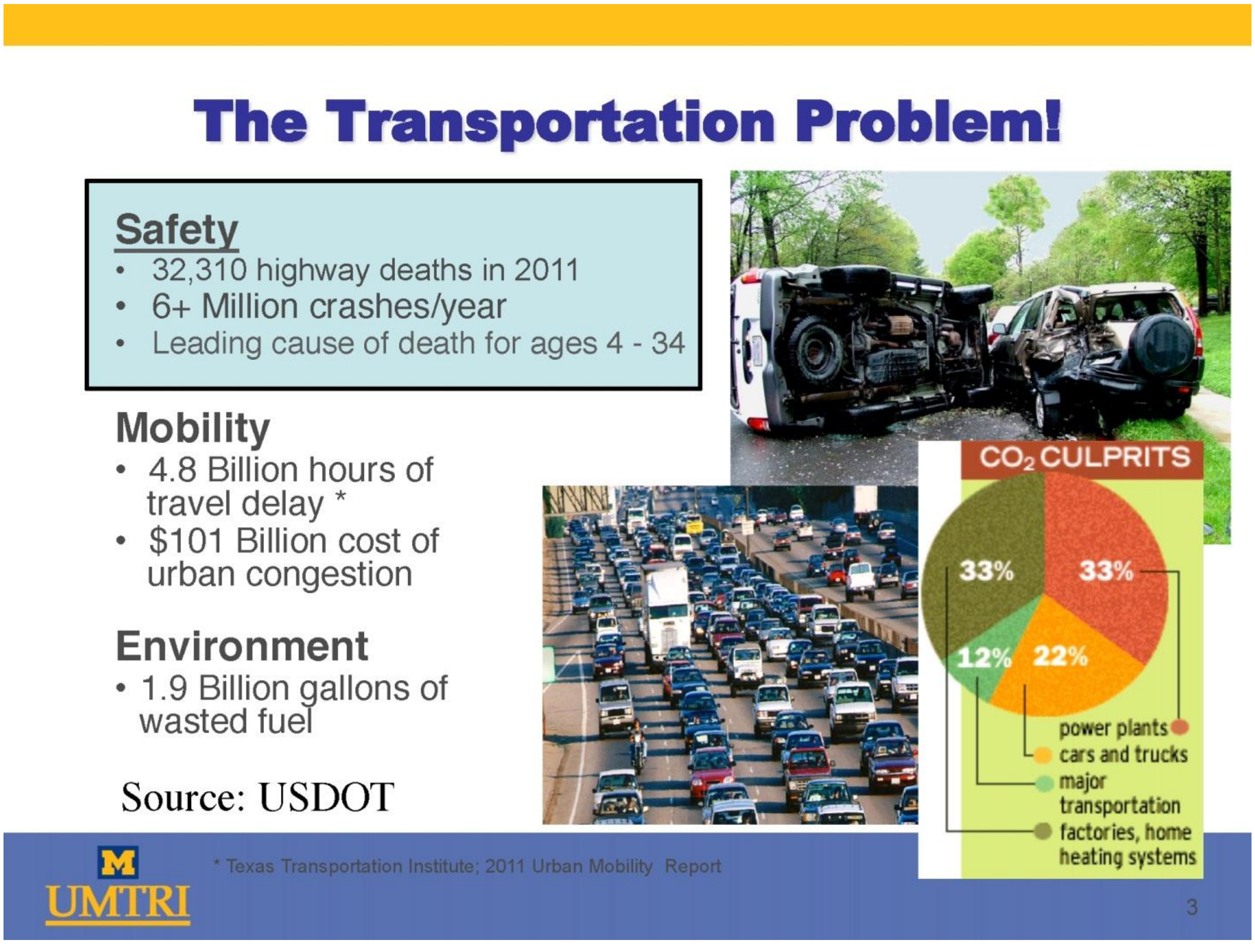
ATTACHMENT 1



The Transportation Problem!
Safety
• 32,310 highway deaths in 2011
• 6+ Million crashes/year
• Leading cause of death for ages 4 - 34
Mobility
• 4.8 Billion hours of travel delay *
• $101 Billion cost of urban congestion
Environment
• 1.9 Billion gallons of wasted fuel
Source: USDOT
CO_2 CULPRITS
33%
33%
12%
22%
power plants
cars and trucks
major transportation
factories, home heating systems
* Texas Transportation Institute; 2011 Urban Mobility Report
UMTRI
3

ITS Opportunities for Higher Safety using DSRC

- **Primary DOT research initiatives:**
  - Vehicle to vehicle (V2V) communications
  - Vehicle to infrastructure (V2I) communications
- **Crash reduction through:**
  - Driver advisories
  - Pre-crash warnings
- **NHTSA Agency decision:**
  - Light vehicles in 2013
  - Heavy trucks in 2014

*V2V+V2I may have the potential to address 80% of the vehicle target crashes involving unimpaired drivers**

Source: USDOT


Work Zone Notification

Intersection Collision Avoidance

UMTRI

*National Highway Traffic Safety Administration, October 2010, DOT HS 811 381

3

Transportation is critical to the nation's economy and way of life

Interstates + state + local roads: asset value of $1.3 T

Highway trust fund will not cover $50 – 100 B annual operating costs

250 million cars require $700 B operating costs

Infrastructure requires significant monitoring & upkeep

Transportation crosses national manufacturing, IT and service sectors

Transportation is lifeblood of economy

UMTRI

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Transportation crosses national manufacturing, IT and service sectors

Transportation is lifeblood of economy

Need "Transportation 2.0"

Intelligent Transportation Systems for Safety

Safety Technologies:

- ✓ Driver Information Systems
- ✓ V2V Driver Awareness Systems
- ✓ V2V Driver Warning Systems
- ❑ V2M Warning Systems
- ❑ V2P Warning and Braking Systems
- ❑ Automated Vehicle Control
- ❑ Infrastructure Awareness and Control Systems

Transportation Data:

- ✓ Driver Behavior/Acceptance through Naturalistic data
- ❑ Vehicle State through Naturalistic data
- ❑ Vehicle State through Telemetric/ Connected data
- ❑ Crash Event Reporting & Analysis through DSRC/cell connection

Transportation 2.0:

Connected + Automated

UMTRI

Intelligent Transportation Systems for Mobility

Congestion & Throughput:

- ✓ Driver Information Systems
- ❑ Driver Routing Systems
- ❑ SPAT “Feedback” Systems
- ❑ Lane Level Traffic
- ❑ Active Traffic Control Systems
- ❑ Smart Parking
- ❑ Platooned Vehicles
- ❑ Off-hour Optimization ….

Operations & Economics:

- ❑ Tolling
- ❑ Managed Lane Access
- ❑ Roadway Health Monitoring
- ❑ Emergency Response

Environment

- ❑ Eco-Driving
- ❑ Electric charging applications….

Transportation 2.0:

Connected + Automated

M UMTRI

Spectrum Sharing

NTIA Report January 2013

- identifies a "number of risk elements due to the likelihood of harmful interference from large numbers of U-NII devices to protected federal systems in the 5350-5470 MHz and 5850-5925 MHz bands."

- …concludes that "further analysis will be required to determine whether and how the identified risk factors can be mitigated…"

UMTRI 8

Spectrum Sharing

Concerns – Safety

- Excessive loading/interference may result in
  - Increased latency
  - Lost packets of data
  - Increase in false positives
  - Could cause degradation of security functions

- Could result in significantly decreased safety benefit

UMTRI

9

Spectrum Sharing

Concerns – Safety

- Could negate results of Safety Pilot
  - Inaccurate measurement of real-world interoperability, cybersecurity, and reliability
  - Delayed warning and resultant driver action
- Could preempt NHTSA decision
- Could delay or stall ITS deployment

UMTRI 10

Spectrum Sharing

Concerns – General

- Reduced mobility benefit
- Reduced environmental benefit
- Reduced economic benefit
- Lowered customer acceptance
- Increased cybersecurity risks

- Doubts about unsure outcome will give manufacturers, innovators, and deployers pause

- Toothpaste can't be put back in the tube

UMTRI 11

Spectrum Sharing

Policy

- Safety spectrum: channels should be reserved and not shared
  - Safety more critical than convenience
- Clear declaration of no sharing for safety/security channels
  - Allows NHTSA to make 2013 decision
  - Removes doubt for stakeholders
- Needs to be clarified now

UMTRI 12

Spectrum Sharing

Policy

- Non-safety spectrum: need definitive testing
  - *Non-interfering* sharing might be helpful
  - Learn from prior interference test regimes
  - No-sharing assumption until test data is available
- Testing must be representative, definitive and represent worst-case
  - Can take the time to prove definitively
- Must include liability considerations

UMTRI

13

Spectrum Sharing

Testing Considerations

- Requires Hardware
  - Representative vehicle, handset, roadside, other devices?
  - Must include software with representative sharing protocols
  - Appropriate ratio of vehicles to other devices
    - 1-to-3?
    - 1-to-10? ….. Higher?

- Must include evaluation of technical challenges
  - “Hidden node” problem
  - “Listen-before-talk” protocol, etc…

- Multi-phase approach required
  - Careful of false negative

UMTRI 14

Spectrum Sharing

Summary

- ITS through DSRC is critically needed to address safety
- Clear policy should be established now to quell doubt
- Safety/security spectrum should be reserved and not shared
- Any sharing of *non-safety* spectrum must be definitively tested before decision

UMTRI 15